MEMORIAV RECOMMENDATIONS

# DIGITAL ARCHIVING OF FILM AND VIDEO:

## PRINCIPLES AND GUIDANCE

VERSION 1.2 | NOVEMBER 2019

The current version of these Memoriav recommendations is available on the Internet at:
**https://memoriav.ch/dafv/?lang=en**

Please get in touch with us if you have any questions, suggestions, additional information, etc.

**New sections**

3.3.4.1 Spherical
3.3.4.2 Anamorphic
3.4.4 Data integrity
4.1.5 Competencies
4.3.3 Film sound

**Sections with revised content**

3.1 Film
3.2.3 Analogue and digital recording
3.2.4 Codecs, containers and compression
3.3.4 Picture format (=aspect ratio)
3.3.5 File format
3.4.2 Stream
4.3.4 Additional comments on film digitization
4.3.8 IT infrastructure
4.4.2 Ethical standards
5.2 Evaluation of common file/video formats and data storage carriers
5.2.2 Supplementary notes on JPEG 2000, Motion JPEG 200 and FFV1
5.2.3 Recommended film formats
5.2.4 Recommended video formats
5.3.2 Storage example: LTO
5.7 Originals
6.4 Additional information

**Memoriav recommendations**
**Digital archiving of film and video**
Translation, November 2019

**Content**
Agathe Jarczyk
Reto Kromer
David Pfluger

**Editor**
Yves Niederhäuser

**Review Version 1.0**
Video/TV Competence Network

**Production**
Laurent Baumann

**Design**
Martin Schori, Biel/Bienne

**Translation**
BMP Translations, Basel

**Published by**
Memoriav
Association for the preservation of
the audiovisual heritage of Switzerland
Bümplizstr. 192, 3018 Bern, Switzerland
Tel. 031 380 10 80, info@memoriav.ch
www.memoriav.ch

Supported by:

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
**Federal Office of Culture FOC**

These Memoriav recommendations have been drawn up by a cross-sectoral working group, reviewed by the Memoriav Video Competence Network and edited and prepared for publication by Memoriav, the Association for the preservation of the audiovisual heritage of Switzerland.

The role of Memoriav is to preserve, develop and disseminate Switzerland's audiovisual heritage. When initiating projects, it gives due consideration to professional standards and ethics. One key task in this field is to draw up and publish recommendations such as these.

The focus of these recommendations is on dealing with digital data of an audiovisual nature. This document is intended to provide guidance and advice on digitization and digital archiving for archivists and curators of collections. It may also be of interest to those in the media production sector as well as anyone submitting project applications to Memoriav, who will be able to find criteria for the long-term preservation of digital audiovisual documents here.

Given the breakneck speed of developments in all fields of IT, regular updates are essential, particularly with regard to specific recommendations. For this reason, these recommendations will be supplemented on an ongoing basis. So when using these recommendations, please check the date and version number of the latest edition.

The digital world opens up excellent new prospects for accessing and making use of archive material. However, preserving digital archive masters calls for the staff responsible to acquire and develop specialist knowledge, and generates considerable additional costs, both for the one-off digitization of analogue documents and also the ongoing maintenance of data. It is vital that these factors are taken into account during the planning phase, and these recommendations provide fundamental advice for this task.

The recommendations provide a basic introduction to the relevant terms and an overview of the issues involved. They also include a general evaluation of the quality of different video formats and their suitability for archiving. However, they do not supply any ready-made solutions or specific instructions or guidance on programs or tools for long-term preservation. These Recommendations take the form of a critical introduction, with the aid of which specific solutions can be developed and then implemented depending on the circumstances in question.

The motivation for digitizing analogue media may have various underlying reasons. One reason that frequently crops up is to preserve material in the long term. But when we probe more deeply, it often transpires that the focus is actually on the benefits of the many different possible applications and the ease of access to documents. Although this indicates a gratifying attitude to dissemination as one of the key aspects of archiving, it often reveals an underestimation of the organizational, technical and financial challenges and consequences of digital archiving.

Digitizing analogue audiovisual documents is in fact becoming increasingly necessary for archives; this applies particularly to films and videos since analogue technology has become virtually unavailable due to obsolescence. What's more, some analogue media are more liable to decay so there is a very limited period of time in which digitization can be carried out with reasonable efforts. In addition, films and videos are increasingly produced digitally from the start and acquired in this form by heritage institutions which then have to develop separate workflows to preserve them.

In the field of digital media, there are even more different forms and formats to get to grips with compared with their analogue predecessors. These are often designed to be used in particular fields of application. Digital material and born-digital media files that are suitable for one field of application may be disadvantageous for another field. Moreover, it is often the initial digitization or the production format that determines the future quality and type of reception. Access to original analogue material at a later date may be restricted for a variety of reasons:

- The original can no longer be found or has been destroyed (originals should be retained even after digitization [Section 5.7]).
- Physical degeneration means the material is no longer of the quality it originally was or the quality it was when originally digitized.
- It is not unusual for analogue originals to be neglected after being digitized, with inappropriate storage leading to accelerated degeneration.
- The technical means and/or expertise to transfer the material at an optimum quality no longer exists.
- No funding is available for a second transfer.

One particular challenge is the generational loss associated with the necessary periodic copying of analogue media. Although digital data can theoretically (and, with proper handling, also practically) be duplicated any number of times with no loss of information, the process of transcoding from one codec to another is somewhat more complex [Section 5.4]. So digital masters do not automatically mean safer long-term preservation. If digital data is to be preserved for a long time, it must be constantly monitored and maintained.

«Digital preservation is an active, long-term commitment; scanning is a time-limited process.»[1]

In order for the results of digital preservation to be correctly evaluated and assessed at a later date, it is important that the process is thoroughly documented. The documentation and transmission of this information are key aspects of digital preservation.

1 LeFurgy, Bill, *Digitization is Different than Digital Preservation: Help Prevent Digital Orphans!*, in: The Signal. Digital Preservation (Blog), http://blogs.loc.gov/digitalpreservation/2011/07/digitization-is-different-than-digital-preservation-help-prevent-digital-orphans/ [9.4.2015]

Some terms, such as «format», are often used rather vaguely in an audiovisual context; the necessary linguistic distinction between film and video frequently gets blurred, perhaps because in everyday language people are only referring to the content or genre, whereas when it comes to the issue of preservation, the (technical) form is essential. To clearly describe the complex technical situations and challenges we are looking at here, the language used needs to be very precise. Some of the key terms are explained below.

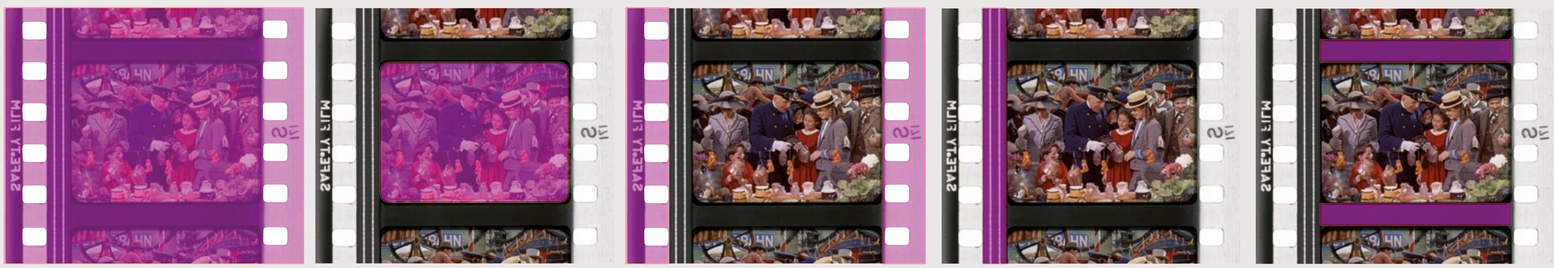
## 3.1 Film

A film is a strip of thin, transparent, flexible plastic that is coated with a light-sensitive photographic emulsion, used for the analogue (photochemical) recording of individual images. Once the film has been exposed during the shooting and the exposed images have been processed and fixed in a chemical process, the image layer is stable and loses its extreme light sensitivity. When correctly played back using a projector, an illusion of movement is created, captured by one or more film cameras by exposing the roll of film as a sequence of individual images. Film exists in various standard widths and in a broad range of emulsions with various characteristics. Film may record images as negative or positive transparencies and may optionally contain sound information as well. It usually has perforations that enable it to be transported image by image in a precise mechanical way. The sound can also be exposed as optically readable analogue or digital information on the film, or it may be recorded on magnetic tape glued onto the film (commag) or a separate magnetic tape (sepmag), on a gramophone record (Vitaphone) or on optical media (DTS). Sepmags are 8 mm, 16 mm, 17.5 mm or 35 mm wide perforated sound tapes with an iron oxide coating that is mounted on a cellulose triacetate or polyester strip.

## 3.2 Video

Video denotes an analogue or digital signal with audiovisual content that has to be interpreted by playback equipment or software in order to be reproduced. The origins of video are closely linked to the history of television technology and magnetic recording. Its typical properties include recording one half of the complete image at a time in an interlaced scanning method and the ability to be replayed immediately without being developed.

Prior to the storage of media-independent files, video was recorded using a wide variety of carriers of differing



Film strip — Image frame — Margin or edge — Audio track — Frame line

**Fig. 1:** Terms relating to surface areas of the film material.

sizes which, with the exception of the earlier transversal recording procedure on 2″ magnetic tapes, all use the helical scan procedure, but on tape widths from ¼″ to 1″ with many different track positions. This gave rise to well over 50 video formats and almost as many different types of tape packaging such as open reels, cartridges and cassettes, which only fit the relevant recording or playback equipment. Further technical progress has resulted in changes in the electronic format (e. g. full frame / progressive scan instead of interlaced), the aspect ratio (16:9 instead of 4:3) and also the medium (e. g. optical data carriers); the biggest change is that video files are no longer media-specific.

### 3.2.1 Video cassette

A video cassette is a magnetic tape in a plastic cassette with a take-up reel and a supply reel, which enables videos to be replayed in specific playback equipment. Depending on the format specification, the length, width and thickness of the tape may vary, and it may have different magnetic properties (coercive force). The tape is intended for use with the video signal of a particular video format [▶ Section 3.3.3].

### 3.2.2 Video player/recorder

Originally a playback or recording device, now also a computer application (e. g. a software player) that can record a digital video signal or play it back from a file onto a computer monitor or projector. An analogue signal must first be converted using a suitable A/D converter so that it can be processed by a suitable software application.

### 3.2.3 Analogue and digital recording

In the analogue recording of video images, the picture signal is divided into lines and written onto a medium such as magnetic tape line by line. When it is replayed, the picture signal is reproduced line by line. To reduce flickering, two half frames are recorded which are then transmitted and read one after another, with each containing only every second line of the image. In this case, the differences in the picture information are recorded as a difference in the intensity of the magnetization.

#### 3.2.3.1 Bandwidth/data rate of the video picture signal

The bandwidth of an analogue picture signal defines the information density of an analogue video picture and therefore its visual quality. It is dependent on factors such as the aspect ratio, the frame frequency and the number of lines in the picture; all factors affecting the quality of the moving image. The bandwidth is specified in Hertz. The European television standard PAL defines a picture with an aspect ratio of 4:3 with 576 visible lines and a frequency of 25 frames per second. A bandwidth of approx. 5 MHz is required for this standard. In the case of digital video, all the picture properties mentioned above are converted into a series of binary numbers (zeros and ones). In digital video, the equivalent of analogue bandwidth is throughput in bits per second, known as the data rate [▶ Section 3.4.2]. In everyday language, people still refer to this as bandwidth even though the unit of measure is completely different.

#### 3.2.3.2 Analogue compression and 4:2:2 chroma subsampling

Explaining analogue compression calls for a brief historical review. When analogue video images were first commercially reproduced in Europe, the CCIR standard was used. This defines a monochrome video picture with an aspect ratio of 4:3 that consisted of 576 visible lines and was reproduced at a frequency of 25 frames per second. In Europe, black and white television sets were manufactured to meet this standard. When color television was introduced, there was a problem because three channels were needed for red, green and blue (R, G, B) to display a color picture. A color picture needed three times as much bandwidth as a black and white picture. The standard that is based on three color channels with 576 lines and a frequency of 25 frames per second is called PAL. So a maximum of one channel could be displayed on old black and white TV sets. This would not be a black and white picture with the correct distribution of various shades of grey, since you would only be able to see a single color separation at most. But this problem was solved using a technical trick. Three new channels were created from the R, G and B channels. One channel contains the black and white picture, equating to information on the brightness of individual image dots (luma). The other two channels contain what are referred to as differential signals depicting color information:

R, G, B → Y, $P_B$, $P_R$
R = Red channel
G = Green channel
B = Blue channel
Y = Luma (brightness information) = black and white picture
$P_B$ = Blue differential signal (B - Y)
$P_R$ = Red differential signal (R - Y)

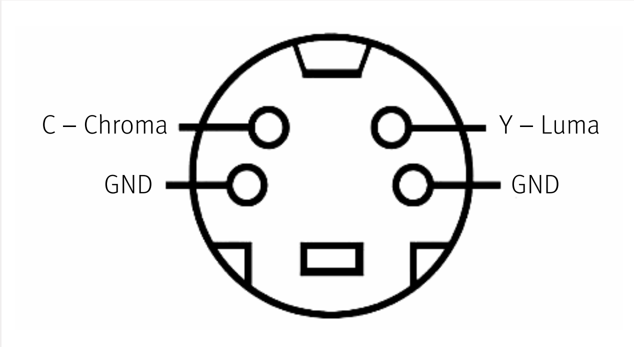
Y, $P_B$ and $P_R$ contain the all the picture information, just like R, G and B. From the information contained in Y, $P_B$ and $P_R$, you can reproduce the red, green and blue channels. R, G, B and also Y, $P_B$ and $P_R$ are called component signals. Black and white TV sets only display the Y channel – the color information is ignored.

This technical trick made it possible to use black and white sets at the same time as color sets, but it did not result in any reduction in the bandwidth required by the component signal compared to the black and white signal. However, by reducing the bandwidth of each of the three channels, it is possible to reduce a component signal to a single channel. This equates to analogue compression, and the resulting signal is referred to as «composite». Reducing the bandwidth always means information will be lost.

Depending on the application it may be necessary to reduce the bandwidth, whereas for other applications it's more important to retain all the picture information. For this reason, a variety of standards were developed that reduce the overall signal by varying degrees, namely from three channels (component) to two (S-Video) or down to a single channel (composite). Once again, technical tricks were used to keep the picture as sharp as possible even when less data was involved. Taking the «Y, $P_B$, $P_R$» signal as the starting point, the two color components PB and PR were reduced to a single channel, each of them having half their original bandwidth (Y/C). This process laid the foundations for digital 4:2:2 compression – one channel at full information density and two at half the information density. Since the brightness information Y is still available in full resolution and only the red and blue color information is reduced, the sharpness of the reconstituted picture is quite well retained. This is referred to as bandwidth reduction or chroma subsampling. Since by definition the analogue PAL picture has 576 lines, halving the bandwidth results in a halving of the horizontal resolution of the red and blue color channels. The green channel can be reconstructed at full resolution from the luma signal. The various conventional chroma subsampling options for digital pictures are described in similar terms (4:2:0, 4:1:1, etc.). A detailed explanation of the nomenclature can be found in Poynton (2002).


Device with the three different types of analogue video connection:
Component (Y, $P_B$, $P_R$), S-Video and composite («video»).

The component connection (colored red, green and blue) consists of three cinch connections, one for each channel:
Y, $P_B$ and $P_R$ and their associated earth connections (cable sheaths).
The S-Video connection has four pins – one for the Y luma signal, one for the Y ground, one for the shared C «chroma» pin for the combined «$P_B$, $P_R$» signal and one for the C ground.
The composite connection consists of a single cinch connection (yellow).




Pin allocation for an S-Video jack

**Fig. 2: Connections for the component (Y, $P_B$, $P_R$), S-Video (Y/C) and composite («video») analogue video signals. This figure shows the typical appearance of the component, S-Video and composite connections on equipment. There are corresponding analogue video formats in which the signal is held on magnetic tape either as a component, S-Video or composite signal.**

Source image in color

**G**
Green color channel (monochrome)

**Y′**
Luminance channel (monochrome)

**B**
Blue color channel (monochrome)

**$C_B$**
Difference signal R–Y’ (monochrom)

**R**
Red color channel (monochrome)

**$C_R$**
Difference signal B–Y’ (monochrom)

**Fig. 3: Color data split into three monochrome color channels.** RGB and $Y'C_BC_R$ are two different ways of splitting up the color data of an image into three channels. The combined data content of the three channels is the same in both cases (the source image above). There are several $Y'C_BC_R$ standards. The one shown here is the SDTV standard.
The color channels are represented in color here for the sake of comprehension. All the channels in fact consist of a monochrome signal that could be displayed in black and white and would not contain any less image data. The $C_B$ and $C_R$ components of the $Y'C_BC_R$ signal are transport signals with the image color data. In reality they are never displayed. The RGB components that are displayed are generated on their basis. Luma channel $Y'$ corresponds to the image that is displayed on a black and white TV when it receives a $Y'C_BC_R$ color image.
The RGB color bars on the right-hand side of the source image have the values 255, 0, 0 for red, 0, 255, 0 for green and 0, 0, 255 for blue in the 8-bit RGB color space. The brightness grey values of the three basic colors shown in luma channel $Y'$ are not identical, i.e. the red, green and blue basic colors are weighted differently in the conversion from RGB to $Y'C_BC_R$. These weightings are the result of technical factors that were in place at the time when color TV was developed. The conversion makes allowance for the way humans perceive color brightness.

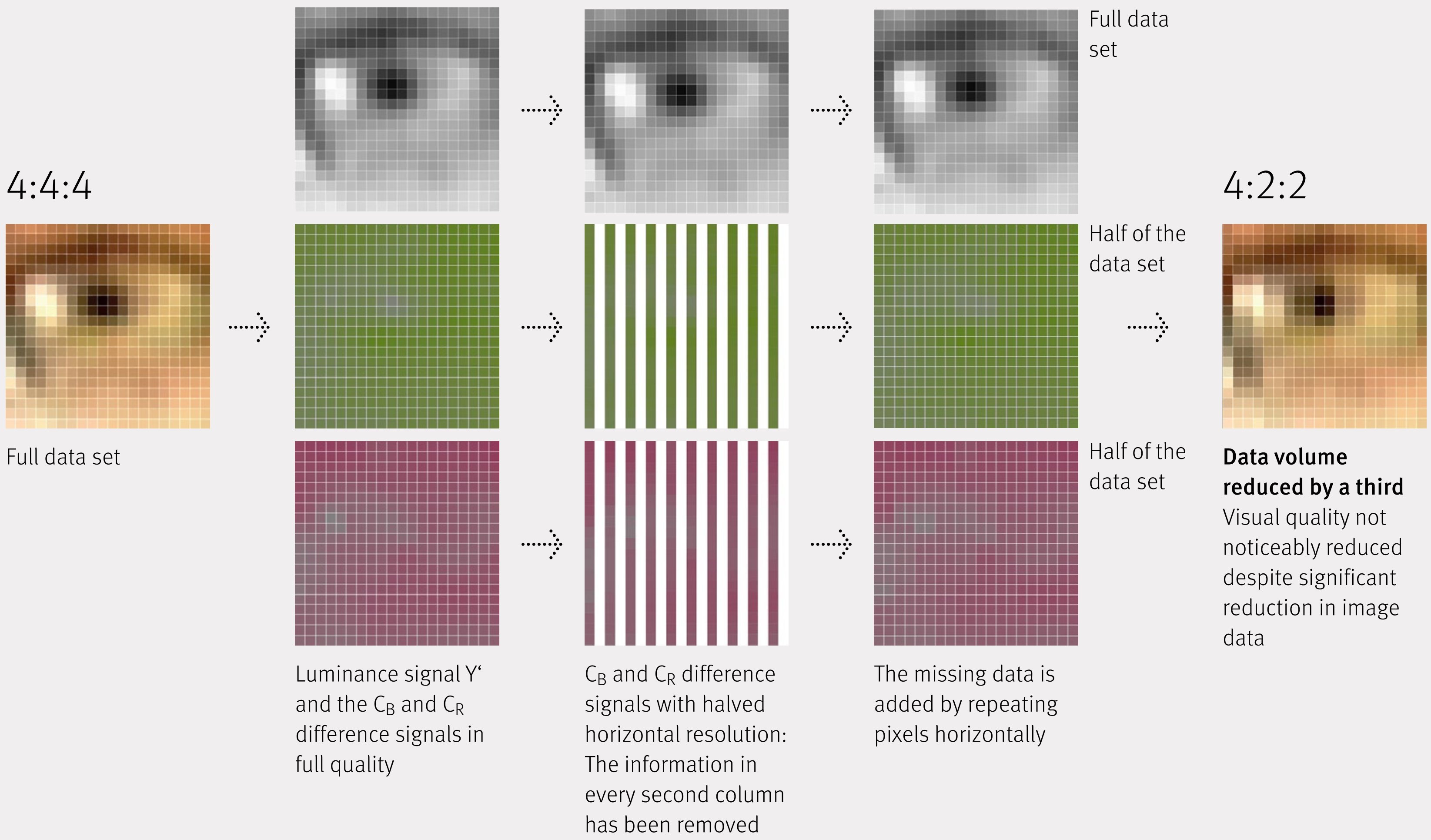



**Fig. 4: Example of compression using 4:2:2 digital chroma subsampling** illustration of data reduction by selectively halving the horizontal resolution of the $C_B$ and $C_R$ difference signals. The images of the U and V channels show that their contribution to image definition is small. The 50 % loss of image data in these channels has a negligible impact on the perceived sharpness of the resulting image.

If a signal of reduced bandwidth is digitized without being compressed, the result will be uncompressed digital, but since the analogue signal has already been reduced, you will not get the same quality you would get if you had used R, G, B or Y, $P_B$, $P_R$ as your starting point.

If you want a display with square pixels, you can calculate the horizontal resolution using the number of lines and the aspect ratio. For a PAL video signal this gives you a value of 768 horizontal pixels. Although the 768 × 576 (4:3) resolution is still used today, the current PAL signal has a resolution of 720 × 576 (5:4) non-square pixels [Section 3.3.4.1].

### 3.2.4 Codec, container and compression

The word codec is portmanteau of coder and decoder. Encoding is the translation of analogue information into a digital code by a coder and possibly also a compressor; to decode the information you will need a decoder, plus an expander if it has been compressed. Encoders can also be used to process files that already exist in digital format, for example if a video signal has been digitized or digitally produced in an uncompressed state and you want to use it to create an MPEG file to manufacture a DVD. This is referred to as transcoding [Section 5.4].

A codec is an instruction to code or decode data in order to reduce the size of the stream or file. This may result in a loss of information (lossy) or not (lossless). There are codecs for the images, for the sound and for the subtitles.

There are a wide variety of different codecs for moving images customized to suit particular areas of application (recording, cutting, editing, streaming, archiving, etc.) because the requirements (and the associated hardware) depend on the particular phase of the video lifecycle. For the same reasons, there are also many different types and versions of codecs with varying qualities. Due to various constraints such as storage space, speed of data transmission and processing, the available infrastructure and funding, it is not usually possible to achieve maximum quality in all phases.

Compression is lossless if the information in the resulting file is the same after coding and merely differently coded. Ideally it should be smaller than the source file.

If there is less information after the (trans)coding process than before, this is called lossy compression. Compression is often not easy to spot visually, even though in some cases it leads to huge losses of information at a data level. This «visually lossless compression» is subjective, there is no definition for it. It is therefore not suitable for archive copies although it may be worth considering for usage copies.

The wide variety is also in the interests of the industry which often uses proprietary codecs and file formats, as it gives it commercial control and generates dependencies.

Compression is primarily used to reduce data volumes so as to achieve lower data transmission rates and generate files that are not quite so big. This speeds up processes and saves on storage space. However, the infrastructure used requires more computing power, which can be relevant particularly in the case of certain very complex, lossless compressing codecs such as JPEG 2000. The question of how much storage space is required is also financially relevant when it comes to secure long-term preservation.

If the post-encoding information is identical to the pre-encoding information, the process is called lossless compression.

If there is less information after the (trans)coding process than before, this is called lossy compression. Compression is often not visually easy to spot, even though in some cases it leads to huge losses of information at a data level (visually lossless compression).

Original image, TIFF
File size 100 %

Lossless LZW compression
File size 55 %

JPEG 2000, lossless compression
File size 41 %

LZW = Lempel-Ziv-Welch algorithm

The efficiency of lossless compression varies considerably depending on the picture content.

There are various methods of lossless spatial compression. One is to group together adjacent identically colored parts of the image. In this way, there is no need to describe the color and location of each individual pixel, which reduces the data volume. In the sample picture, a section of black has been outlined with a dotted line. All the pixels in this area have the same RGB color value of 0, 0, 0. Lossless compression algorithms make use of such properties in images.

**Fig. 5: Lossless compression.**

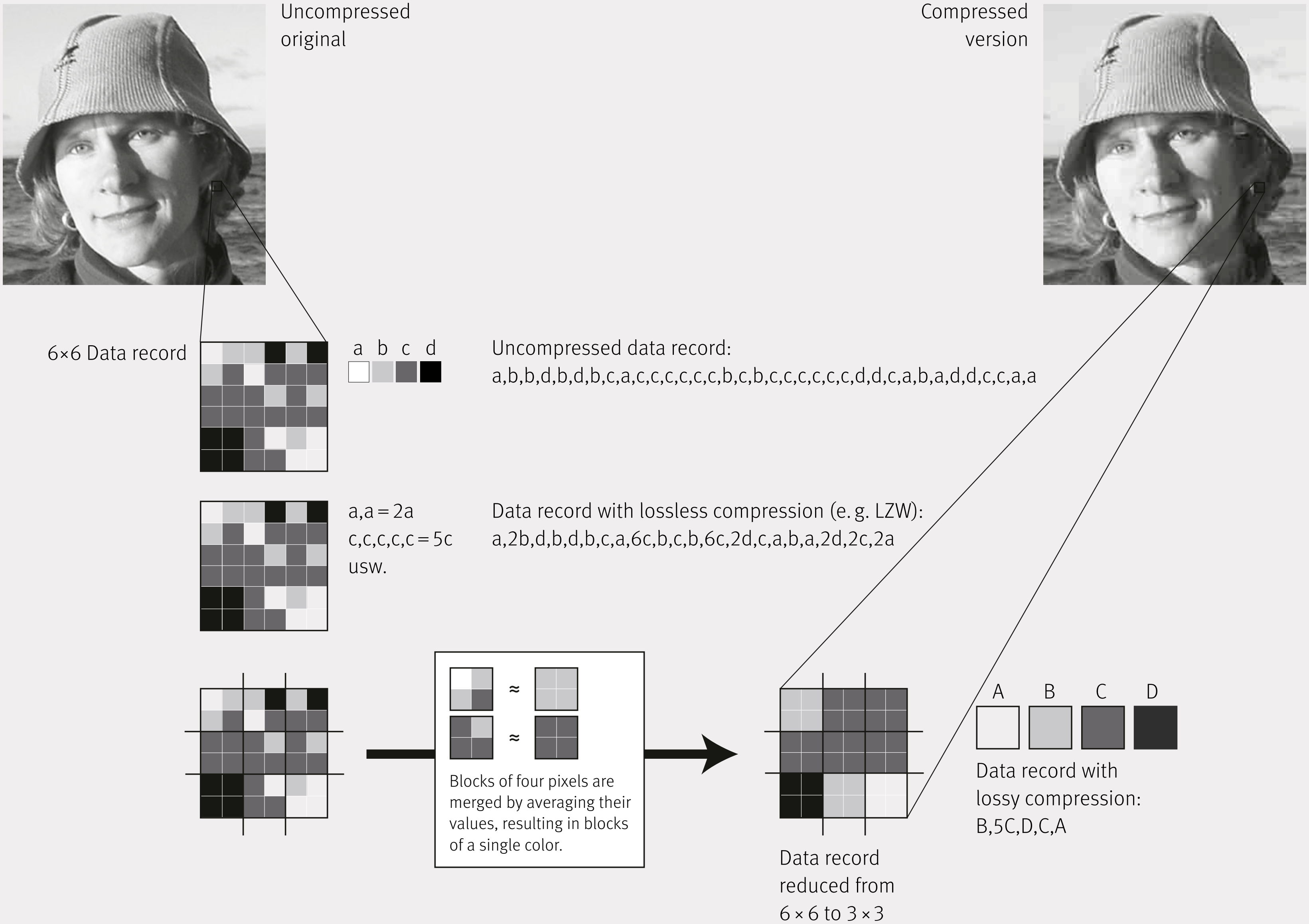



**Fig. 6: Spatial compression.** In the example shown, a data set with 6 × 6 pixels with four different gray values each is divided into 2 × 2 data sets. The gray values of these data sets are mathematically unified, resulting in a 3 × 3 data set with half of the original horizontal and vertical resolution. The spatial compression does not reduce the image information uniformly over the entire image area, but with different intensity depending on the information density of the image components. Image areas with a high information density are less strongly compressed than those with less dense image information (e. g. blue sky).

Most of the codecs are based on a compression algorithm. These algorithms may vary quite significantly. For example, some procedures compress individual images (known as intraframe compression [▶ Fig. 5]) and others compress a sequence of images (known as interframe compression).

Depending on the codec concerned, it is possible to set the compression rate or the data rate. So simply specifying which codec has been used does not allow you to directly infer the type or extent of the compression. This information has to be explicitly stated. The range of codecs is constantly being expanded in order to increase their efficiency and adapt them to new applications. This increases the risk of, which is particularly relevant for long-term preservation.

The container stores the data coded by the codec in a file, combining image, sound and other information. It makes sure that the image and sound data are provided to the player synchronously, i. e. it coordinates the work of the video and audio codecs. Containers contain the following elements among others:

– video codec and video data
– audio codec and audio data
– subtitle codec and subtitle data

## 3.3 Format

In the field of media, the term «format» is often used vaguely and to mean different things. To avoid any confusion and misunderstanding, some more precise definitions of terms are given below.

### 3.3.1 Media format

These days all the technical means of mass communication between people are generally called media, for example radio, the press, the Internet, etc.

In an audiovisual context, medium refers to the technical form of the means of communication.
Example: video, film or file

### 3.3.2 Film format

In the film industry, film format denotes a technical standard that is determined using the following attributes:

– Film width and perforations in the film material
– Dimensions of individual frames (aspect ratio)
– The number of perforations per frame or the distance from the start of one frame to the start of the next.
– The direction in which the film travels in the camera (vertically or horizontally)
– The frame frequency (frames per second, fps)

Example: Super 8, 16 mm, 35 mm

35 mm and Super 16 are professional film formats, as are formats wider than 35 mm. 8 mm, Super 8, 9.5 mm and 16 mm are referred to as small gauge film formats. Although «normal» 16 mm film was also introduced as an amateur format in 1923, it too became a professional format until the introduction of Super 16, and was used as a production format in TV for decades.

### 3.3.3 Video format

Video format is a top-level term that refers not only to the various data carriers such as cassettes and open reels with their own individual properties, but is also used in the context of data files. The latter are more precisely specified using the terms container and codec. The following attributes and technical standards are used to define video formats:

– Carrier type, such as cassette, cartridge, open reel, disc, etc.

– Method of storage: optical, magnetic, magneto-optical.
– Type of recording, specific signal (e.g. U-matic Low Band or High Band, DVCAM or DV)
– Frame frequency and scan type (frames per second, fps, interlaced or progressive)
– Frame size and aspect ratio (SD, HD, UHD)

Example: Betacam SP PAL, HDV 1080i or HDV 720p

### 3.3.4 Aspect ratio

The picture format describes the ratio between the width and height of a picture (1) and the way in which the image is projected, in other words spherical vs. anamorphic (2). Examples of (1): 16:9, 4:3 (video), 1.37:1, 1.66:1 (film), etc.

The picture format is referred to below as the «aspect ratio».

Different audiovisual media have different aspect ratios. Transferring material from one audiovisual medium to another (e.g. film → video, analogue video → digital video) may involve transferring to a different aspect ratio. The most common example of this problem is transferring a 4:3 picture to an aspect ratio of 16:9. This can be done in a variety of ways:

– Pillarboxing (= curtains, pillar box)
– Enlarging and cropping (loss of picture at top and/or bottom)
– Pan and scan (variable picture loss)
– Distortion (incorrect aspect ratio)

Each of these solutions has its own particular advantages and disadvantages, and should be used in a well-informed manner depending on the particular application in question. Chance or a lack of knowledge should not constitute the key factor here.

The priority is to maintain the aspect ratio, so for originals with an aspect ratio of 4:3 the only option is to convert them to 16:9 by pillarboxing. By doing so, the entire display area remains in the correct aspect ratio for future use [▶ Fig. 6+7].

If an image is transferred to a wider picture format without being cropped or distorted, you will get a black bar on the left and right sides (known as a pillar box or curtains). If it is being transferred to a narrower picture format, you will get a black bar at the top and bottom (letter box).

#### 3.3.4.1 Spherical

In contrast to an anamorphic lens, a spherical lens displays objects without distortion. It is called spherical because the shape of its two surfaces corresponds to a segment of the surface of a sphere and is thus, among other things, rotationally symmetrical. Greek: sphaira = ball, sphere, celestial sphere.

Spherical lenses produce imaging errors which are referred to as spherical aberrations. These effects are corrected in modern lenses by slight adjustments to the shape of the surface. These lenses are then referred to as aspherical. In contrast to the anamorphic lenses, however, their shape is only slightly different from the surface of a sphere.

Copies of cinema movies are sometimes referred as «spherical 35 mm prints», i.e. these are current copies that can be projected without an anamorphic lens. A «spherical print» of a CinemaScope film is either horizontally cropped to a 4:3 or wide-screen aspect ratio or projected with a smaller image size and «letterbox» bars.

#### 3.3.4.2 Anamorphic

The term anamorphic comes from the Greek word anamorph which means «formed again». It is used to refer to optical lenses that distort the image of an object.

| Format | Interlaced/ progressive | Aspect ratio in pixels | | Display (virtual pixels) | |
|---|---|---|---|---|---|
| **SD PAL** | e, p | 720 × 576* (5:4) |  | **4:3** (768 × 576) |  |
| Anamorphic | | 720 × 576 |  | **16:9** (1024 × 576) |  |
| Cropped | | 720 × 434 |  | **16:9** (1024 × 576) |  |
| **SD NTSC** | i, p | 640 × 480** (4:3) |  | **4:3** (640 × 480) |  |
| More modern standard | | 720 × 480 (3:2) |  | **4:3** (640 × 480) |  |
| **HD** «Full HD» | i, p | 1920 × 1080 (16:9) |  | **16:9** (1920 × 1080) |  |
| **HD** | p | 1280 × 720 (16:9) |  | **16:9** (1280 × 720) |  |
| **HDV** Anamorphic «Full HD» | e | 1440 × 1080 (4:3) |  | **16:9** (1920 × 1080) |  |

* The total number of lines in SD PAL is 625. But only 576 lines are used for picture information.

** The total number of lines in SD NTSC is 525. Only 480 lines are used for picture information, although certain video formats use 486 lines. Two 4:3 standards are commonly used for the horizontal sampling rates for SD NTSC.

**Fig. 7: Comparison of information density of common video formats.**

| | Film with an aspect ratio of 4:3 | Area covered by picture | Film with an aspect ratio of 16:9 | Area covered by picture |
|---|---|---|---|---|
| **2K**<br>2048 × 1556<br>1:1.31 (4:3) |  | 2048 × 1556<br>(100 %) |  | 2048 × 1152<br>(74 %) |
| **2K DCP**<br>2048 × 1080<br>ca. 17:9 |  | 1440 × 1080<br>(72 %) |  | 1920 × 1080<br>(94 %) |
| **Full HD**<br>1920 × 1080<br>16:9 |  | 1440 × 1080<br>(75 %) |  | 1920 × 1080<br>(100 %) |

**Fig. 8: Comparison of the film surface area used for films with aspect ratios of 4:3 and 16:9 for 2K, DCP 2K and Full HD standards.** Film and video technology has generated a large number of different film and video formats. The flexibility of displaying images digitally has expanded the range of possibilities and therefore the number of standards even further. The fact that there has been a transition from a 4:3 to a 16:9 aspect ratio in the cinema and on TV over the last 30 years is reflected in the complexity of standards and subsidiary standards. Figure 5 (page 16) provides an overview of the common standard definition (SD) and high definition (HD) video standards and their resolution in pixels. The aspect ratio in pixels often does not correspond to the aspect ratio of the display. You can find more information on this in Section 3.3.4.1.
Emerging digitization in the film technology led to the 2K and 4K standards being defined for sampled film images. 2K and 4K relate to the maximum area of a 35 mm film image between its perforations, and have 2056 and approx. 4112 horizontal pixels respectively. The conventional 35 mm image, which extends across 4 perforations, has an aspect ratio of 4:3, giving you 2056 × 1536 pixels for 2K and 4112 × 3072 pixels for 4K. The modern digital projection standards for cinema are also called 2K DCP and 4K DCP, but relate to an image that has an aspect ratio of approximately 16:9. 2K DCP has 2056 × 1080 pixels and 4K DCP has 4112 × 2160 pixels. This can lead to confusion, since the two 2K and 4K options are not optimized for the same aspect ratio. This problem is illustrated in detail in Figure 6.

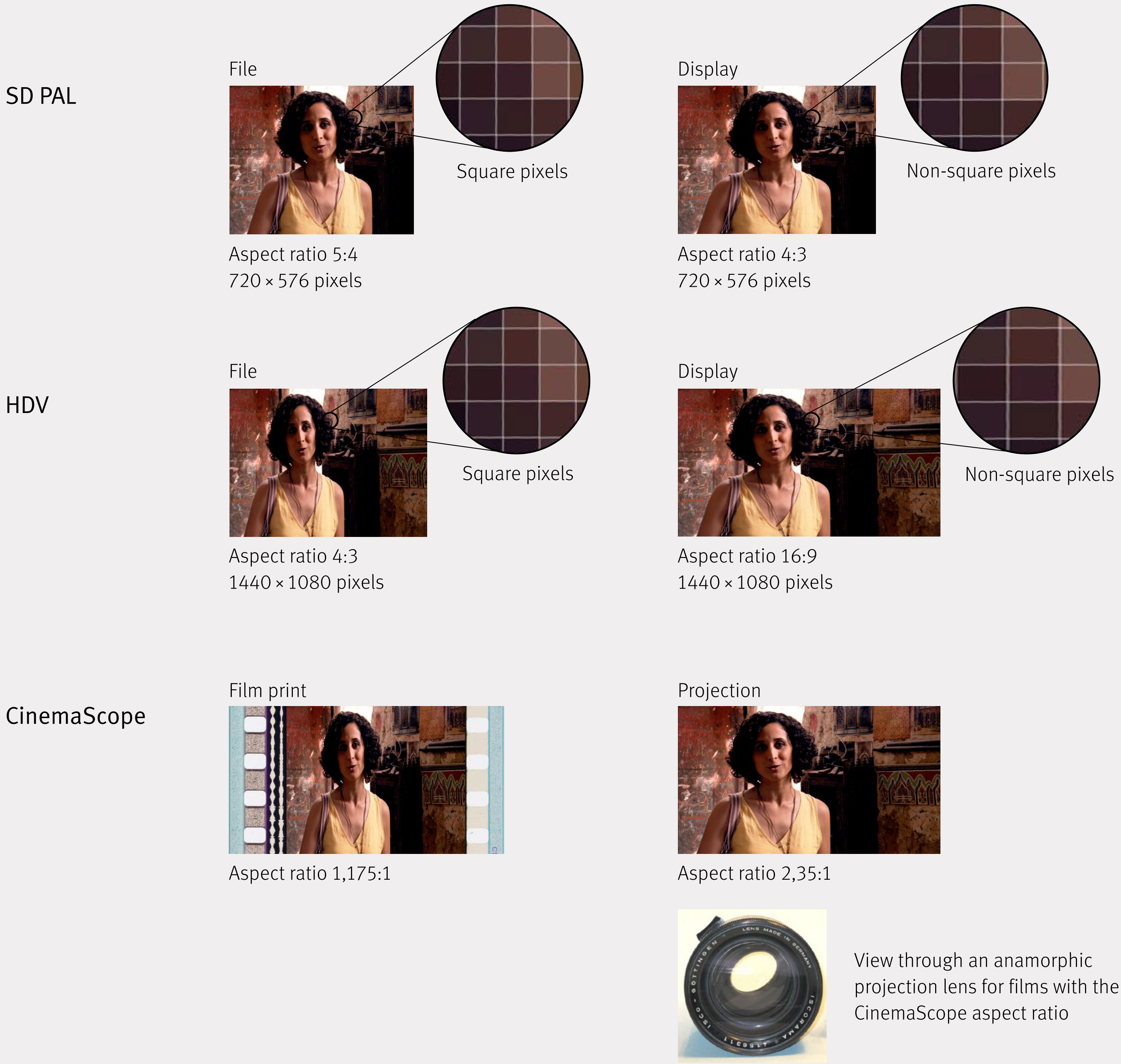



**Fig. 9: Some examples of square and non-square pixel displays and their counterpart in conventional film technology.**

Anamorphic lenses squeeze or stretch the image in one direction and are the main type of lens used in classic film technology. They allow widescreen formats like CinemaScope to be filmed in the best possible quality on 35 mm film and then to be projected with the correct aspect ratio [Fig. 9]

The maximum image frame on 35 mm film with an optical audio track is 21.9 mm wide and 18.6 mm high. This corresponds to an aspect ratio of 1.18:1. The CinemaScope image which has a 2.35:1 aspect ratio can be produced with a lens that horizontally squeezes the image at a 2:1 ratio while shooting and another lens that horizontally stretches it again at a 1:2 ratio during projection. If an image with an aspect ratio of 2.35:1 were to be filmed without distortion, it would make very poor use of the film surface area (letter boxing).

The anamorphic process just described was adopted for digitally recording and playing motion pictures. A variety of approaches were developed because the aspect ratio of the sensors in cameras often does not correspond to the changing aspect ratio requirements of the output format and also to allow cameras to record in different aspect ratios. They use both anamorphic optics and digital scaling to distort and correct the images. The term non-square pixels is used for digital images that are stored in a different aspect ratio than they are displayed [Section 3.3.4.3].

Videos stored in a different aspect ratio than they are to be displayed are normally digitally scaled to the correct aspect ratio by the player software at the time of playback. To do this, the player requires metadata with information about the display aspect ratio which may be stored in the file header or in the container metadata [Section 3.3.5]. The metadata in these two locations may be conflicting. Which information is used or prioritized depends on the player.

#### 3.3.4.3 Square and non-square pixels

Pixels are essentially the basic square building blocks of a digital image. They possess a value denoting a shade of grey or a color. The aspect ratio of an image displayed in pixels is the full number of pixels across its width to the full number of pixels from top to bottom, divided by the largest common divisor of these numbers.
Example: «Full HD»: width: 1920 pixels, height 1080 pixels = 1920/120:1080/120 = 16:9

However, certain video formats are stored in file formats but not in the pixel aspect ratio in which they are going to be displayed. Example: SD PAL: width: 720 pixels, height: 576 pixels = 720/144:576/144 = 5:4

Display aspect ratio: 4:3.

In this case we refer to non-square pixels, because the pixels in the display have to be stretched horizontally in order to get from the 5:4 ratio to the 4:3 display ratio. In the case of SD PAL, this stretching amounts to 6.66 %. The picture's information density remains the same, but the pixels are now rectangular rather than square.

The reason this display format is used for SD PAL has its origins in conventional video technology. In the case of HD video formats, it is an additional means of saving information, in other words, a type of compression.

These days, all common projectors and monitors display pictures using square pixels. If a file contains rectangular pixels, it will have to be converted by a graphics card.

A similar situation exists in conventional film technology. The extremely wide CinemaScope picture with its aspect ratio of 1:2.35 is exposed on 35 mm film, which was originally intended for 4:3 pictures, as a horizontally squeezed 1:1.175 picture using an anamorphic lens, and then stretched out during projection, again using an anamorphic lens [Fig. 7].

### 3.3.5 File format

This is the digital code used to store the information. Some file formats can incorporate several different types of files. These formats are known as containers (or wrappers). In an audiovisual context, containers may contain a variety of codecs [3.2.4 Codecs, containers and compression] and streams [3.4.2 Streams], i.e. video and audio in different codecs as well as additional information such as time codes, subtitles and metadata, depending on the type and flexibility of the container.

Pure file formats such as AIFF (.aif) or DV (.dv) are seldom. Most file formats are containers, such as PCM audio in a wave container with a file ending of .wav or a DV codec video in a QuickTime movie container with a file ending of .mov. Container formats are used so that a variety of elements (e. g. different codecs, individual images, time codes) can be stored in a single file to facilitate multimedia displays. Another reason for using containers relates to archiving – to keep supplementary files such as metadata text files

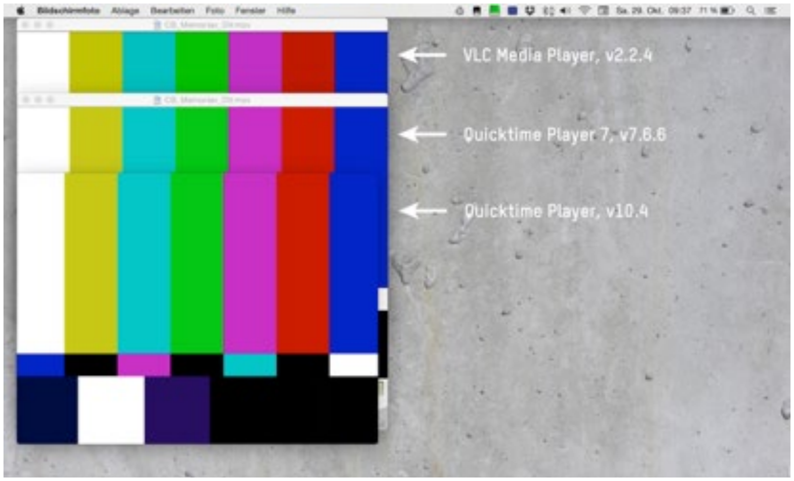



**Fig. 10:** Software players may prioritize the metadata of the video codec and the container differently. This may result in the same file being displayed in different widths, for example.

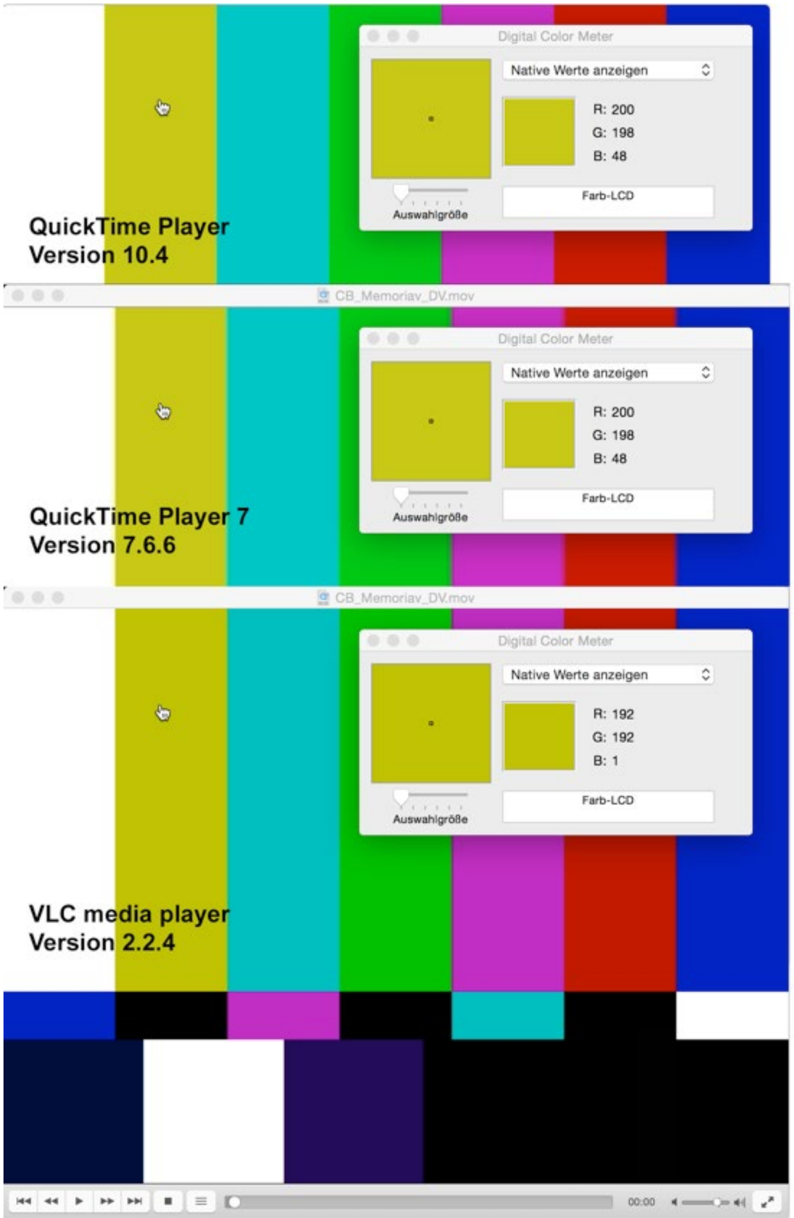



**Fig. 11:** Another important distinguishing feature of the various software players is that they use different codec libraries. This is one of the causes of color variations in the display of the same file by different players.

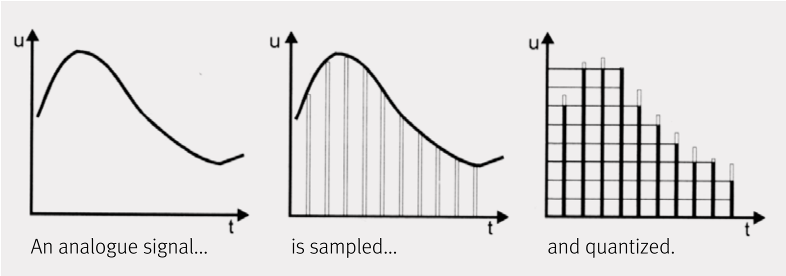



**Fig. 12a:** Sampling with a narrow time matrix.

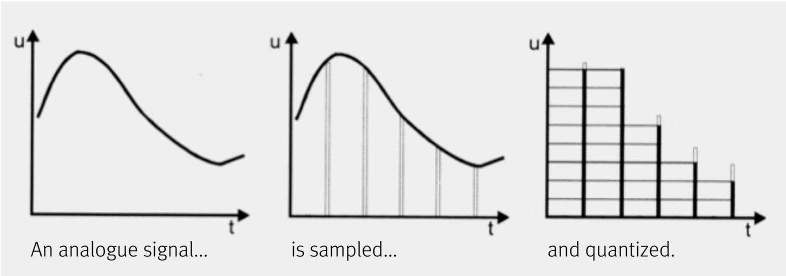



**Fig. 12b:** Sampling with a broad time matrix.

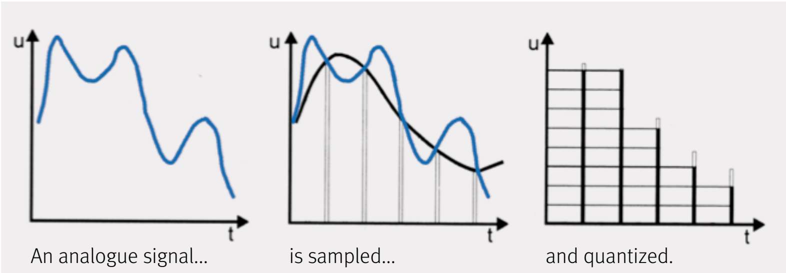



**Fig. 12c:** If the sampling rate is too low, the reproduction will be poor.

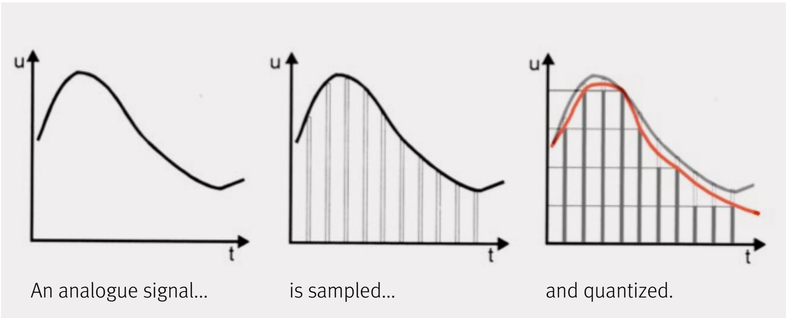



**Fig. 12d:** If the quantization is reduced, the amplitude will be poorly reproduced.

together with the video and audio files – as is possible with the MXF container, for example. Not all container formats, however, offer the same possibilities in this regard.

As when selecting the appropriate codec, it is generally advised to select the container type carefully, to ensure that it is well suited to the existing or future IT infrastructure (operating system, playback and editing software, etc.). The QuickTime player, for example, has not been supported on Windows operating systems since mid-2016. To play back videos stored in QuickTime movie containers (.mov), other software players, which may not support all the original functionalities, now need to be used. Care should also be taken when transcoding or switching from one container to another [Section 5.4 Codecs and transcodings], because there is always the risk of losing important metadata (e. g. aspect ratios or color space), elements (e. g. time codes) or certain characteristics (e. g. frame rates).

It is virtually impossible to provide an overview of all the relevant features of the containers and how to use them in the respective players. However, it is recommend to test and evaluate a variety of containers and players and their functionalities in different combinations. The various software players differ in their functionalities such as play and rewind, how to access individual frames, the way the audio volume and time code are represented and other specific display options. Apart from the differences in functionality, the presentation itself may also vary depending on the combination of software player, codec and container [Fig. 10 and 11].

### 3.3.6 Archive format, access format

The lifecycle of an audiovisual production can broadly speaking be divided into the following phases: shooting, post-production, distribution/screening and archiving. Each phase has a range of specially tailored file formats. These are assigned to the phases as follows:

#### 3.3.6.1 Shooting format

The file format or physical video format in which the pictures were recorded in camera on set. The shooting format determines the maximum possible image and aesthetic quality.

#### 3.3.6.2 Post-production format

File format in which video is processed (editing, color grading, special effects, etc.). For this reason, the post-production format is also referred to as the processing format. The original quality of the material can be impaired by unsuitable applications and codecs during post-production. The weakest link in the chain will determine the quality of the end product. Ideally, the quality of the original shooting format should not be undercut during any stage of post-production. In the context of archiving, the term «mezzanine format» is used. Such formats do not contain all the information, but they do contain enough for them to be further processed (e.g. color grading or editing) without any defects becoming visible in the picture. Common mezzanine formats include Apple ProRes 422 HQ and ProRes 4444 or Avid DNxHD and DNxHR 444.

#### 3.3.6.3 Access format

Can be one of many usually highly compressed file formats that have been optimized for viewing in a particular context. This might be distribution and screening in cinemas, broadcasting on television, projection in public places or at home, or consultation via the web. The quality can vary from IMAX standard to very modest «YouTube quality». The access format permits material to be viewed at the correct speed. However, it is very difficult if not impossible to process the material any further; for example, it would be virtually impossible to correct the color. Various terms are used depending on the context. In film libraries, cinemas and museums, terms such as screening, projection and dissemination format or copy are used, while in archiving terms such as access, consultation or viewing copy may be used, or even more general terms such as in OAIS which uses DIP (dissemination information package).

#### 3.3.6.4 Archival format

A file format in which video, film and sound documents are stored and maintained so they remain usable for as long as possible. Preservation and archive masters are stored in the archival format. These are the files that are to be stored in the long term. Ideally they should contain all the information that was generated during the digitizing process. But since film scanners generate proprietary intermediate formats, these should be converted into a standardized format. For films, it is usually an RGB color space with 4:4:4 sampling that is currently used, while for videos and television it is generally $Y'C_BC_R$ 4:2:2. For archive formats, it is also very important to document exactly «where» the white is within the color space.

NB: Archival masters are not suitable for screening. Each time they are screened or used, the master gets worn away and there is a risk of defects or damage occurring due to improper handling (data loss).

1 bit per color channel:
$2^1 = 2$ colors per channel
A total of $2^3 = 8$ colors

3 bits per color channel:
$2^3 = 8$ colors per channel
A total of $8^3 = 512$ colors

5 bits per color channel:
$2^5 = 32$ colors per channel
A total of $32^3 = 32{,}768$ colors

8 bits per color channel:
$2^8 = 256$ colors per channel
A total of $256^3 = 16{,}777{,}216$ colors

**Fig. 13: The bit depth (or color depth) as a quality factor in digital images.** The bit depth in a picture is usually specified separately from the compression information. Just like spatial resolution, this is not compression, but it does determine the limits of the sampling rate for the color information in the digitizing process. This sampling rate has a significant influence on the picture quality. At a low bit depth, even an uncompressed picture will appear visually deficient. All the pictures shown here are uncompressed. Their quality is defined by the spatial sampling rate, the resolution (which is the same in all the examples) and the sampling rate for the color channels, in other words the bit depths of the different color channels.

## 3.4 Digitization

In an audiovisual context, digitization means converting an analogue signal into a digital code using an A/D converter. In colloquial speech, the term digitization is often used imprecisely (e. g. for manufacturing files or in general terms for the increasingly pure digital use of audiovisual media), and is often confused with the term ingest, which only means the same thing in certain cases. In certain cases, transcoding (the conversion of data from one code to another) may also take place.

### 3.4.1 Digital coding

Digitizing video and audio signals takes place in three steps. First of all sampling, then assigning values (quantizing), and then generating a number sequence. So there's a time matrix (t) and a value matrix (u). The resolution of the time matrix is known as the sampling rate. The more frequently the values are read, the higher the sampling rate (t). The sampling depth, also known as the bit depth [▶ Fig. 13] – determines the resolution of the value matrix (u). The sampling rate and the bit depth both determine the quality of the digitization of an analogue signal.

### 3.4.2 Stream

The term stream or streaming generally refers to (1) a bit stream or (2) video streaming. A bit stream (1) is a sequence of bits that represents some information. The structure and encoding depend on the file format and codec used. The data rate or bit rate defines the amount of information streamed in a given time unit and determines the size of the stream. Streaming (2) enables you to watch a media file via a network without needing to download the entire file beforehand and without storing the file on the target device.

### 3.4.3 Data carrier

Magnetic or optical carriers devices may be intended for a specific video format or may contain any type of digital data. Both options usually exist for any given type of carrier. For example, the cassettes used for the analogue Betacam SP video format were subsequently used in exactly the same physical format for Digital Betacam and for the DTF digital tape format. Playback devices recognize the different carriers by using notches at certain positions on the cassette. Lay people can only distinguish between the cassettes using the color code (for information on identifying individual data carriers and file formats ▶ Section 4.2). In the same way, a CD-R someone has burned themselves cannot be distinguished from an audio CD they have also burned themselves. They can only identify the nature of the content with the aid of a reading device. Different data carriers may therefore appear virtually identical but may use different read and write technology; some can be read using the same drives and others cannot. The following table lists some properties and examples for dedicated and non-dedicated data carriers:

| **Dedicated data carriers** | **Non-dedicated data carriers** |
|---|---|
| Properties | |
| Can only store one file format | Can store any file format |
| Analogue and digital formats | Only digital formats |
| Directly replayable | Not always directly replayable |
| Examples | |
| DVD video | DVD-R |
| Digital Betacam cassette | DTF data tape |
| 35 mm cine film | Data «recorded» on film |

So a DV format video may exist in an identical quality and format on different data carriers, for example on a DV cassette or on a hard disk drive (HDD) as a .dv file. The data is identical but the playback technology is different. This automatically affects how the stored moving images are perceived. Different characteristics, such as the conventional PAL video format with its interlaced line structure cannot be reproduced and perceived in the same way on a modern monitor designed for progressive reproduction as on a conventional cathode ray tube display [Section 4.4].

#### 3.4.4 Data integrity

Data integrity is key to digital archiving. File fixity is a digital preservation term that refers to a file being fixed to prevent it from being changed and to ensure that a file is an authentic copy of the original as a condition for storing it. Changes or corruption can occur during a transfer (e.g. due to interruptions), through active use (e. g. incorrect handling) or even static storage (e. g. as «bit rot»). Data integrity checks (fixity checks) should therefore be conducted in the archiving workflows of every transfer and as an (automated) routine within the archive [Section 5.3.3]. Ideally, the process should allow errors to be detected at individual image and file level by producing checksums [Section 5.3.3], for example, at all these levels and archiving them together with the documents. It is especially important to have checking mechanisms at these various levels because the massive data quantities and/or file sizes in AV archives mean that considerable savings in resources (work, time, computer capacity) that can be achieved by identifying and correcting errors. Certain containers like Matroska (.mkv), and codecs such as FFV1 and FLAC support automated data integrity checks as standard options.

### 3.5 Metadata

Metadata is produced throughout the entire lifecycle of an object, from when it is produced right through to when archivable files are created. Therefore metadata should be well structured in order to be able to easily and reliably use the constituent parts that are relevant for a particular application. The metadata that is needed for content searches differs from that needed for scheduled broadcasting or editing, for example. Indexing information, documentation and even metadata are particularly essential for long-term preservation. Without solid metadata, it is very difficult if not impossible to use and manage archive material in general and digital files in particular.

Based on their different functions, a distinction can be made between technical, descriptive, structural and administrative metadata, although the boundaries between these categories can sometimes be rather fluid.[2]

Technical and, in the case of more complex files, structural metadata contains information that is needed to replay the file contents, and also information on how the file was created and processed. The scope of technical metadata varies depending on the infrastructure and file format used, and is not explicitly defined. Technical metadata is often stored in the file's header record, but can also be stored elsewhere within the data structure, particularly in the case of containers. The header is a part of the file code in which information can be stored in text form. It is worthwhile mentioning e. g. EXIF (Exchangeable Image File Format) data in this context. This is written directly to file headers, for example in JFIF (JPEG) and TIFF image formats. A lot of technical metadata, such as the creation and amendment dates for digital documents, is automatically created and can be

2 See Gregorio and Stepanovic, 2008, *KGS Guidelines*, 3/2008, p. 13 f.

displayed by image processing applications. Some of this information cannot be changed, but some can be created and amended either for individual files or as a batch process for several files. This is determined by the file format in question, and special software applications are needed to edit the data [▶ Section 5.6 Toolboxes]. If additional (e. g. descriptive) metadata needs to be included, a suitable container format will be required, into which the AV file and associated metadata can be packaged.

Descriptive metadata may contain any type of information on the context (e. g. author and creation date) and content (e. g. image descriptions and keywords), and serves mainly to locate, identify and understand the file contents. It is usually recorded in an indexing database (a catalogue, inventory or similar) and stored and managed separately from the AV file. But as mentioned above, descriptive metadata can also be integrated into a container file to reinforce the link between the metadata and documents for long-term retention. Descriptive metadata should ideally be recorded in accordance with systematic rules and also standardized by using metadata standards such as Dublin Core, EBUCore or PBCore [▶ Section 5.5.1].

Administrative metadata is used to manage documents and may contain information on editing, the document's status and associated elements relating to rights, evaluation decisions and selection decisions. In connection with preservation, the PREMIS standard in particular is worth mentioning. This can be used to document conservation information such as condition, restoration and digitization in a structured manner. PREMIS forms an integral part of the Swiss Matterhorn-METS standard, which is used in various Swiss heritage institutions [▶ Section 5.5.1].

## 4.1 Planning principles

Digitization and digital archiving must be carefully planned if it is to be sustainable, efficient and secure. Solid planning principles are needed for this purpose, some of which are specific to the audiovisual sector (technology, obsolescence, infrastructure, costs, etc.). The first basics needed are an inventory (an overview of scope and structure) and an analysis of the documents to be archived (existing formats, condition, content, etc.), so as to be able to estimate what you're dealing with. You then need to define objectives (of the preservation for posterity and possible uses), draw up plans for evaluating, indexing, long-term preservation and access (with associated backup plans in each case), evaluate the digitization strategy (e. g. in-house or external, formats, quality, etc.), estimate costs and establish priorities.

Most of these principles will depend to a very large extent on the context, so decisions will need to be made based on the context and any available leeway. Such decisions cannot be generalized. However, the following principles can be generalized:

- Make well-informed decisions that are not solely based on technical issues, but take into account all the specified aspects and conform with the policies of the institution concerned.
- Establish a modicum of in-house expertise, even if working with external service providers; internal control of the deliverables or digital material, the handling of these or responsibility for them cannot be outsourced [▶ Section 4.1.5].
- Operate at an inter-disciplinary and cross-departmental level. Archiving managers and IT managers should plan together from the very beginning.

### 4.1.1 In-house or outsourcing?

Heritage institutions can undertake digitization and data conservation themselves provided they have or can obtain the necessary infrastructure, knowledge, funding and staff. The volumes of media that are to be digitized must be sufficiently large in order to exploit economies of scale that justify such a move and the associated expenditure. Otherwise, it is more cost-effective and reliable to delegate the task to specialist service providers. However, it's difficult to define what constitutes a «critical mass», since this is dependent on a variety of factors:

- The amount of material that already exists and the anticipated growth in AV document volumes (mandate, collection strategy, area of jurisdiction, etc.)
- HR capacity (staff expertise, time required, staff training)
- Technical infrastructure (capacity and maintenance)
- Financial options and security (long-term investment and operating costs – which media and storage devices can be processed in the archive?)
- Physical infrastructure (space, air conditioning)
- Range of existing media and data storage devices (uniformity)
- Whether digitization is to be a short-term project or an ongoing medium to long-term task

A list of audiovisual service providers in Switzerland and useful information on procurement is provided on the Memoriav website

### 4.1.2 Quality control

Quality control plays an extraordinarily important role in the digitization and digital archiving of film and video. This must be factored into the relevant workflows, since there are many potential sources of errors and it is neither quick nor easy to identify these. This is irrespective of whether the digitization is going to be carried out in-house or externally. If external service providers are involved, quality control must be clearly defined in the relevant requirements specifications and other contractual agreements, and the contracting organization must have procedures and tools in place with which to validate the deliverables. Some general guidance is provided here on quality control and some specific recommendations are given below.

The main objectives of quality control in the digitization of audiovisual recordings are to preserve this material for the long term, gather information for preservation planning purposes and thereby to enable archiving itself to take place. In other words, the quality control criteria that focus on these objectives are different from those of post-production (as are the format selection criteria, for example). This is also particularly important when it comes to choosing and using tools (hardware and software), because not all of them check the same parameters. Quality criteria relating to preservation are aimed at maintaining authenticity rather than obtaining the most attractive image quality, for example.

Quality control for digitization begins with the handling of the physical originals that are to be left in their original condition. Any variances (e. g. the use of barcode, etc.) must be clearly agreed and kept to a minimum since, for long-term preservation, archive material should ideally be free from any foreign material and stored in inert packaging. The individual preparatory steps (such as cleaning and heat treatment) must also be agreed in detail between the client and the service provider.

Maintaining the image and sound information in the condition in which it was supplied is of paramount importance during the actual digitization process: «enhancement» is not the objective of digitization for preservation purposes. The principal aim is to create digital material that is as authentic as possible, and tools can be used for this purpose such as TBCs for stabilizing the video signal and a wet gate for reducing the effect of scratches during film sampling. More extreme measures such as retouching images or adjusting colors should only be carried out with the client's prior agreement. Ideally, the unaltered digital material should also be archived in such cases. If the original recording includes reference signals (video) or reference images (film), these should also be transferred.

Any adjustments to the signal path (e. g. the use of TBCs for video or wet gates for film) and any conversions (e. g. from SECAM to PAL) should be agreed in detail, and signal manipulations should be checked using suitable instruments such as a waveform monitor or vectorscope. Agreement should be reached on the scope (100 %, random sampling, none), timing (at what points during the workflow) and nature of these checks (automated and/or manual) plus how to deal with the results (repeat the operation, discard the results, etc.). The resources to be used for this purpose (hardware and software, checksums, collection/extraction of metadata, etc.) should be specified in detail. Criteria to check during digitization include:

- Matching the transfer with the existing metadata (e. g. duration, content)
- Synchronization of image and sound
- Color/black and white: check using color bars, reference images, white balance
- Presence of a time code
- Comparison between versions
- Language/subtitles
- Image errors (video: dropouts, skewing, etc.; film: picture steadiness, focus, etc.)
- For films: the area of the film surface to be transferred (aspect ratio, with/without perforations)

And finally, agreement must be reached on how the results of checks are to be passed to the client. Long-term preservation depends on systematic documentation that is preserved with the films and videos. In terms of content, this means:

– clearly naming the various physical recordings and files (original, master, exhibition copy, archive copy, access copy, etc.),
– documenting all the measures undertaken from receipt through to delivery (transport, storage, preparatory treatment, playback and recording devices plus cable connections for video, scanner model for film or digitisation method),
– documenting the physical original if this has not already been done: make (format, brand, type, emulsion), detailed external description (labelling, identifying features, possibly a photo) plus specifications for recording audio and video (e. g. sound on longitudinal tracks, video in long-play mode) or film image and sound (e. g. optical Dolby SR sound, sepmag),
– documenting the digital file: codecs and containers with associated specification, check sum.

As well as the content, the format (text, table, database, XML, etc.) and any standards used (METS, PREMIS, etc.) should be clarified in advance.

Once externally digitised films and/or videos are delivered, the following things should systematically be checked:

– Check sum (integrity)
– Completeness of documentation
– Technical properties of the files defined as preservation elements (do they match the details in the requirements specification? what about validation?) with regard to structure (e.g. does the container match the specifications? do the contents of the audio tracks match the specifications?) and content (duration, file size, etc.).

Before awarding the contract, the question about how to deal with any quality variations vis à vis the requirements specification should be clearly adressed, and before going ahead with the full job, it is worthwhile doing test runs of the anticipated workflows, after which any system errors or problematic terms of reference can be modified. After checking the deliverables, the commissioning institution will decide whether any follow-up work or deliveries are needed. Ongoing, timely quality checks that are as automated as possible, particularly where large volumes are involved, are strongly recommended.

### 4.1.3 Costs

The costs for the digital archiving of audiovisual collections will always be composed of various elements. In addition to the usual expenditure for acquisition, evaluation, indexing, etc., there may be costs involved in clarifying rights and, in particular, costs for processes of a technical nature such as digitization, transcoding and storage. As already mentioned, economies of scale should be taken into account when considering these technical processes. Be aware that costs may vary significantly from provider to provider, sometimes because different additional services may be included in the quotation, or because the technical infrastructure used is more or less expensive.

Digitization costs will depend greatly on the type, scope and condition of the original material and the quality requirements of the digitization process. For example, processing and digitizing an hour of 16 mm film in poor condition can cost many times more than the same task for an hour of 16 mm film in good condition. And dealing with video art will be much more time-consuming than dealing with videos that are of purely documentary interest. Transcoding costs will depend on the formats of the existing and target files. When it comes to storage costs, economies of scale should be factored in; since storage is an ongoing operating cost rather than a one-off project cost, this expenditure needs to be planned somewhat differently.

### 4.1.4 Staffing and organization

The field of long-term digital preservation is so extensive and complex that it cannot realistically be treated as a «sideline» to day-to-day operations. Anyone who does not have day-to-day dealings with IT issues and archiving will not be able to gain sufficient knowledge and experience to operate in a considered, long-term manner. And the world of IT is changing extremely rapidly, so managers will constantly need to keep up to date.

Depending on the size and structure of the archive, it may not be possible for existing staff to deal with it. In this case, appropriate jobs will need to be created or a supplier must be found who can be entrusted with these issues.

In order to operate a digital archive, good communication and cooperation between the archiving department and the IT department are vital. Both departments must be clear on the principles of archiving and the basics of backups and storage in an IT context.

### 4.1.5 Competencies

Strategies, concepts and infrastructures should be designed in such a way that a heritage institution with the purpose or mandate of digitally archiving film and video can perform all the important tasks for working with digital film and video files itself – playing the files, creating user copies and edits, etc. – regardless of whether the material was or is digitized externally or whether management of the repository is outsourced to a service provider. Only in this way can control over the material be maintained and, possibly, even income be generated.

In addition to the conventional skills, specific expertise in the digital archiving of film and video is required in order to deal with the main archiving tasks (backup, evaluation, sourcing, preservation, access) and take responsibility for the archives. Heritage institutions that archive film and video or whose employees carry out this work must have the following knowledge and skills:

- Knowledge of media history: knowledge of the production, distribution and usage contexts as well as the material is required for identifying films both materially (format, recording type, etc.,) and functionally (e.g. «original» or copy). This is essential in order to appropriately plan, prioritize and implement measures to preserve, evaluate, source or distribute these films and videos.
- Knowledge of AV file structure: knowledge of codecs, containers (wrappers) and timecode(s) is required in order to make well-informed decisions regarding target formats and preservation planning, and for assessing offers, checking delivery objects, etc.
- Advanced IT user skills: Above-average user skills are required in order to use the less common functions of popular tools (e.g. VLC with two monitors) or indispensable open source tools. This also includes keeping an eye on relevant developments in IT in order to be able to respond appropriately to changes (new tools, obsolescence, services no longer provided, or similar) at the appropriate time. This task cannot be fully outsourced to IT departments because they rarely work with archive-specific open-source software and because they often cannot assess the requirements for digitally archiving cultural assets.

- Basic knowledge of the command line interface (CLI): Sometimes important functions or programs cannot be used with a graphical user interface (GUI); either because there is no GUI or, if there is one, not all the required functionalities can be accessed through it. Moreover, batch processes, such as verifying checksums, transcoding user formats, extracting meta data are often only possible from the CLI.
- Minimal programming knowledge or a basic understanding of scripts (e. g. in Bash, Python, Javascript, PHP): This is required in order to automate processes within the existing infrastructures or to check or adjust the respective scripts, e. g. to reflect the signatures used in the archive.

## 4.2 Identifying formats

Identifying the formats of existing media is one of the initial tasks of every digitization project. This is also important in order to find service providers for external digitizing or equipment for internal consultation or digitizing, and also to be able to estimate costs. Identifying content, the various versions and the status of the existing copies are also essential basic activities that are central to evaluation and prioritizing, but these do not fall within the scope of this document.

### 4.2.1 Identifying carrier and file formats (film and video)

Identifying existing physical (analogue and digital) data carriers calls for specialist knowledge that is not widely available. A range of tools are available that can be used for this task.

#### 4.2.1.1 Identifying video tape formats

- Memoriav (Hg.), *Video. Die Erhaltung von Videodokumenten*, 2006, http://memoriav.ch/video/empfehlungen-video/ [1.10.2019]
- Gfeller, Johannes, Jarczyk, Agathe, Phillips, Joanna, *Kompendium der Bildstörungen beim analogen Video*, Zürich, 2013
- The Little Archives of the World Foundation / ECPA, *Video Tape Identification*, o. O., 2008, http://www.little-archives.net/guide/content/formats.html [1.10.2019]
- Stauderman, Sarah, Messier, Paul, *Video Format Identification Guide*, o. O., 2007, http://videopreservation.conservation-us.org/vid_id/ [1.10.2019]
- Texas Commission on the Arts, *Videotape Identification and Assessment Guide*, 2004, https://www.arts.texas.gov/wp-content/uploads/2012/04/video.pdf [1.10.2019]

#### 4.2.1.2 Identifying film formats

- National Film Preservation Foundation (Hg.), *The Film Preservation Guide. The Basics for Archives, Libraries, and Museums*, o. O. 2004, https://www.filmpreservation.org/preservation-basics/the-film-preservation-guide [1.10.2019]
- Pritchard, Brian R., *Identifying 35 mm Films*, o. O., 2011, http://www.brianpritchard.com/35mm%20Film%20Identification%20Version%203.2.pdf [1.10.2019]
- Pritchard, Brian R., *Identifying 16 mm Films*, o. O., 2013, http://www.brianpritchard.com/16mm%20Identification%20Version%201.02.pdf [1.10.2019]

The identified carrier formats should be specified in an inventory, if possible with all the aforementioned defining characteristics [▶ Section 3.2.3].

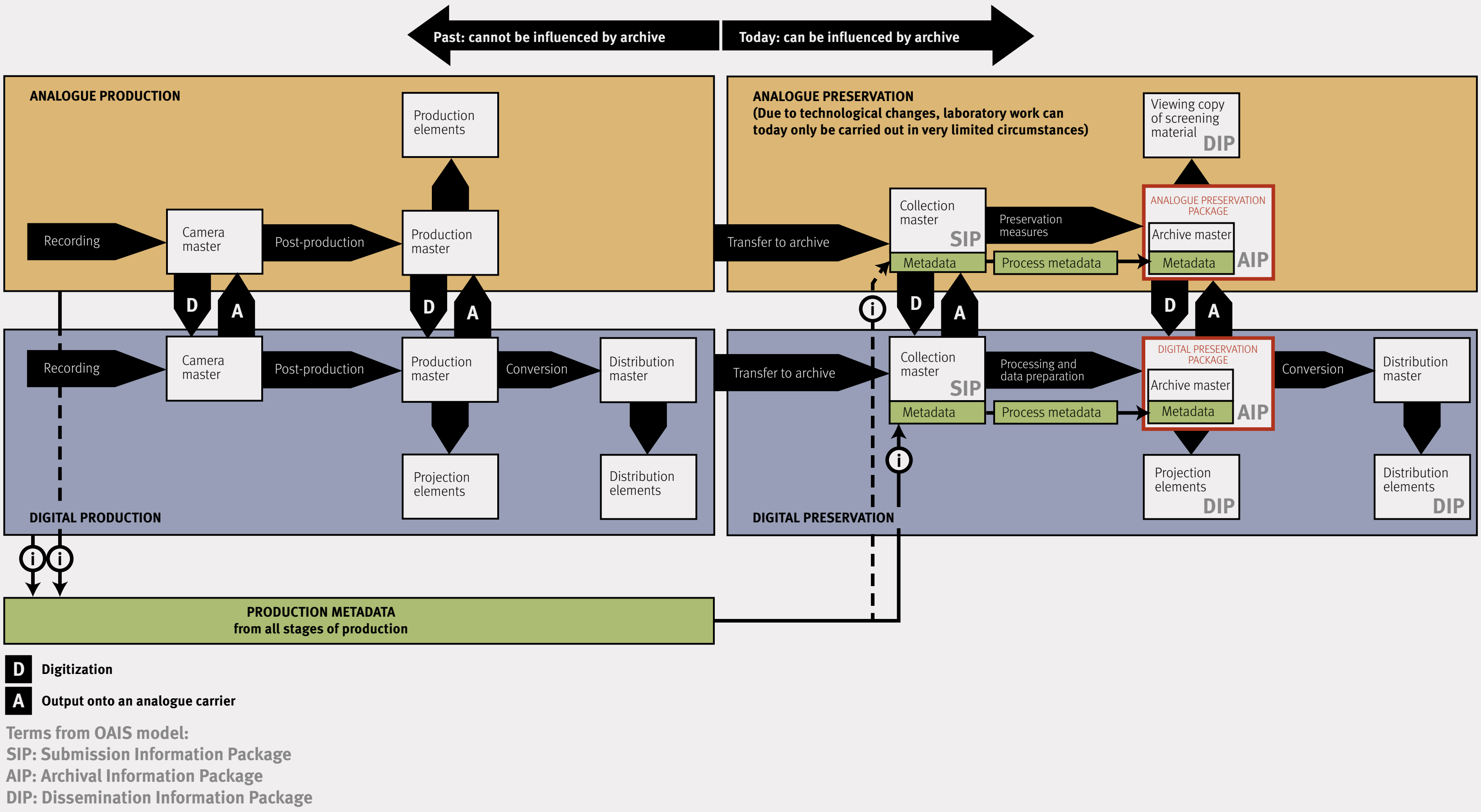



**Fig. 14: Film workflow.** Overview of film processes from recording to backup package in archive.

### 4.2.2 Identifying video files

Identifying video files is more difficult than identifying analogue storage formats because it cannot be done by using directly recognizable external characteristics. So it is all the more important for long-term preservation that format information and technical specifications are well documented. If this information is not available or if it needs checking as part of a quality control procedure, a range of simple tools is available for this purpose. These are listed in the «Toolboxes» section [Section 5.6]. However, the scope and reliability of these and similar tools varies, and in some cases they will not be adequate. Professional equipment and advice may be necessary.

## 4.3 Digitization in archiving

Archives can essentially acquire media from all stages of the production process [Fig. 13 and 11]. The items contained in archives can be purely analogue, digital or mixed. In a digitization process, analogue audiovisual material such as films or videos is digitized, processed and then used for a particular purpose. For various reasons [Section 5.7], the analogue (or digital) originals should continue to be archived as well.

### 4.3.1 Digital preservation/restoration vs. digital post-production

The methods used in preservation and post-production are essentially similar, but the focus and therefore the requirements are very different. One of the preconditions for post-production is creative freedom, and the technical focus is on conventional formats that are suitable for current production. In contrast, preservation/restoration is based on ethical principles that constrain what processing can take place [Section 4.4], with the focus lying on formats suitable for long-term use. So the starting point is fundamentally different, and for this reason the choice of methods and the file formats used may also differ. And the digital re-processing of old films does not always result in a restored version in the strict sense of the word; this requires the ethical principles mentioned above to be followed.

When post-production service providers and archive managers work together, it's important to clarify the terms of reference and agree on clear common terminology, because in these two fields the same terms are often used to mean different things (and vice versa).

### 4.3.2 Film from recording to archiving

[Fig. 14].

### 4.3.3 Film sound

The impression of film restoration is often that the main focus is on the images and that the sound plays an ancillary role, even though, in the days of silent movies, film was always presented with accompanying sound, and the continuous development of movie sound right up to the digital multi-channel sound systems in modern cinemas contributed significantly to enhancing the cinema experience.

In film preservation, sound is also often treated as a side issue. However, the fact that there are many very different technical types of film audio tracks and a great variety of proprietary multichannel sound systems poses a challenge to preservation. Making sure that image and sound are synchronized is also not always easy.

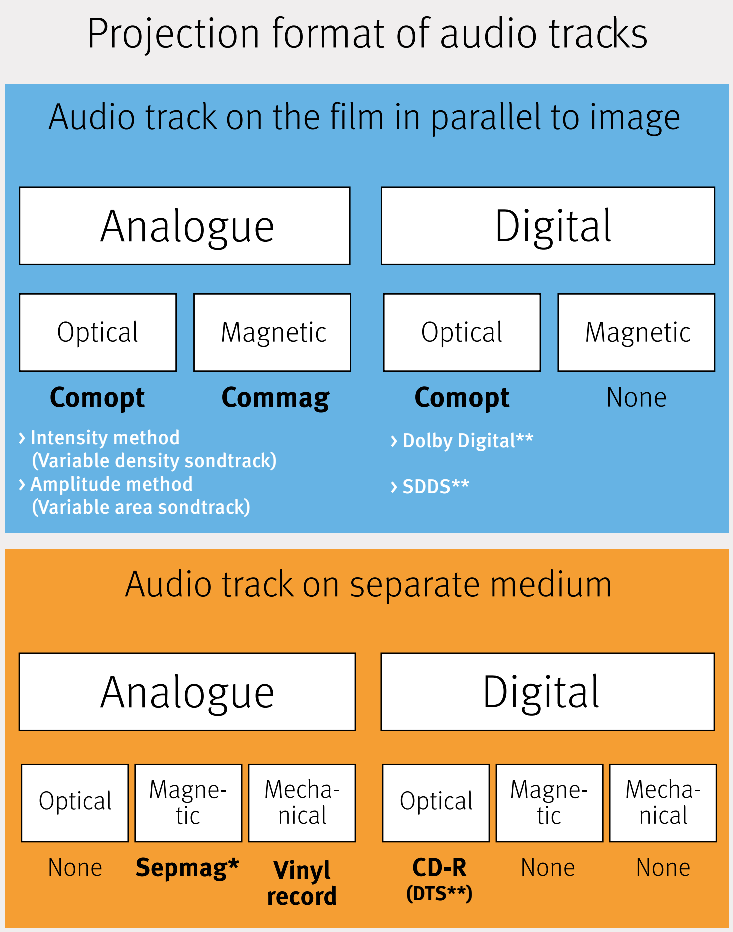
#### 4.3.3.1 Synchronization of sound in classic cinema films

There are basically two ways to deal with the technical challenge of playing the images and the sound in sync:

1. The sound is added as an audio track onto the film strip in parallel to the image and read by an audio head that is located at a defined distance from the film gate. This offset between image and sound is standardized for film formats.
2. The sound is on a separate medium, and the audio player is linked to the projector either mechanically or via a control signal.

For both these options, there are digital and analogue solutions that are stored on optical or magnetic media. For projection formats the audio track is usually recorded onto the film and read optically. On modern film copies with digital optical multi-channel tracks, there is usually an additional analogue audio track (usually in Dolby SR) which serves as a backup in case there is a problem with the digital system or if the movie is to be shown in a cinema that does not have Dolby Digital sound. Modern films therefore often have multiple audio tracks. Digital film sound is however only used with 35 mm film and broader formats. It is not used with 16 mm film and smaller formats. Small gauge film is almost always recorded in mono. Two-channel stereo sound is only found on small gauge film if there are two composite magnetic (commag) audio tracks. Some 16 mm films have both an optical and a magnetic audio track. This format was developed by Kodak for in-flight entertainment systems and was also popular in Switzerland, e. g. with SSVK (Schweizer Schul- und Volkskino) and the TCS.

In the case of commag copies, a thin magnetic strip is glued onto the film. This track is on the edge of the film and can be recognized by its brown color. Because the film rests on its edge when transported in the projector and the addition of the magnetic strip on the film makes it thicker on one side, a «balance stripe» was added to certain small gauge films. This is a second, usually narrower track on the other side of the film that balances out the position of the film strip. Some suppliers then introduced the option of




* Sepmags as audio tracks for projection in the cinema are fairly rare. They were usually used in film post-production or for the master with the final mix to produce analogue optic sound negatives. On the other hand, sepmag was almost always used for TV productions on film which was the main recording medium before it was replaced by video.
** Protected product name of a proprietary sound format.

**Fig. 15: The main categories of audio tracks for projection formats.**

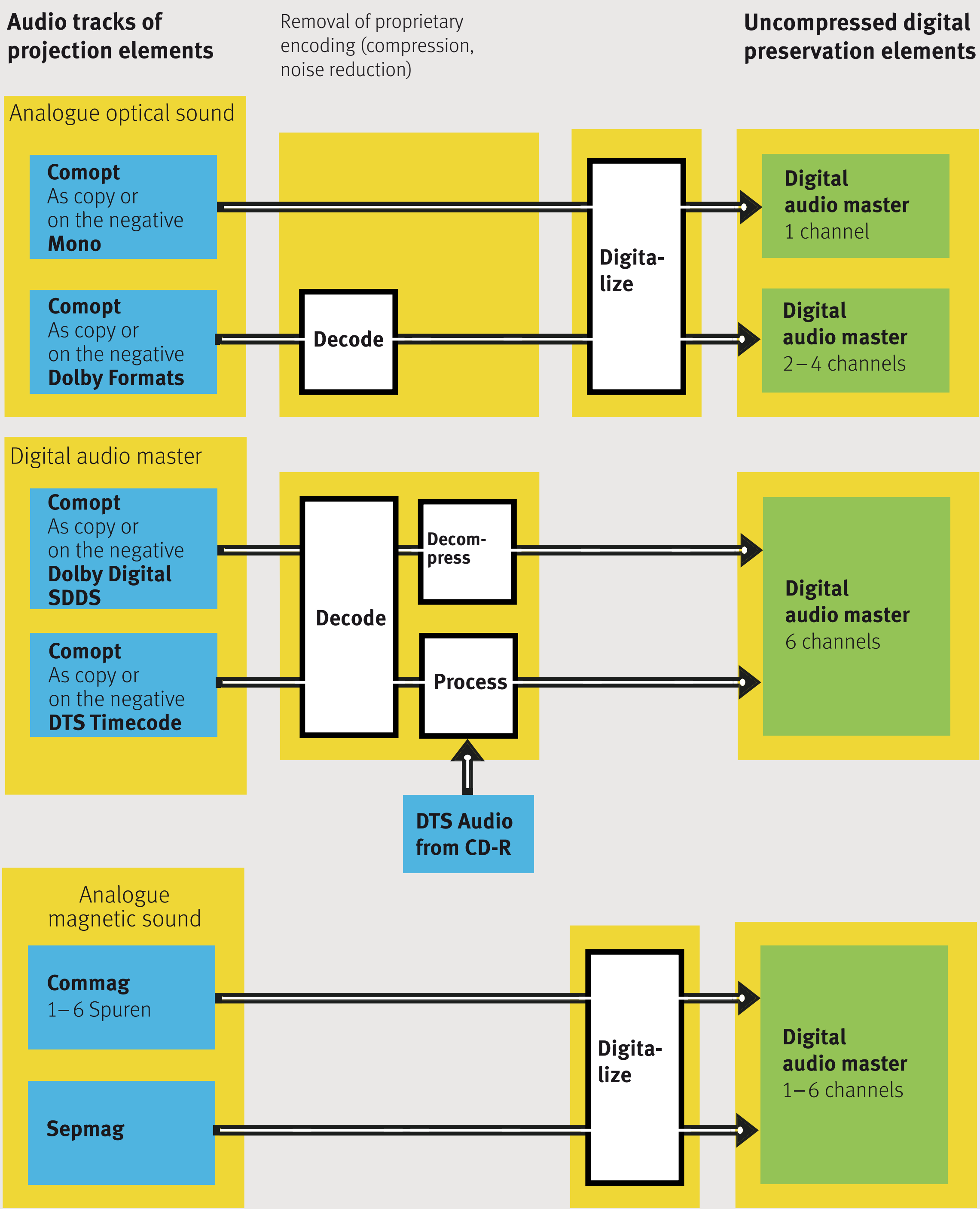



**Fig. 16:** Overview of the sequence of steps to convert the audio elements created for projection into digital elements for long-term preservation.

recording sound onto this track as well. The additional track was either used as a second mono track (e. g. track 1: voice, track 2: music) or as one of two stereo tracks.

#### 4.3.3.2 Normalisation of audio tracks for digital archiving

Often, the only available source elements for digital archiving are the projection elements of the audio tracks or post-production elements containing the final mix. The aim of normalising these audio elements for preservation purposes is to end up with a series of separate uncompressed or lossless compressed audio tracks that are allocated to the original channels and are exactly the same length as the associated image elements. This requires proprietary systems to be decoded and lossy compressed ones to be transcoded into file formats that are suitable for archiving.

Fig. 16 provides an overview of the steps required to convert the main projection formats into digital archiving elements.

#### 4.3.3.3 Digitization of analogue optical audio tracks

There are two fundamentally different strategies for digitizing optical sound:

1. The sound is read with the audio head designated for this function. It is essential to be aware that a more modern audio head will not necessarily produce better results. There are many types of analogue optical audio tracks, and generally one must assume that the best results are achieved with an audio head from the time of production. The reason for this is not only to prevent quality issues such as distortions but also to achieve the original characteristics of the sound.

2. One approach that produces great results and has seen tremendous development in recent years thanks to increases in computer performance is to scan the optical audio track as an image. The computer converts the digitized image into sound. One important advantage of this process is that the image of the audio track can be digitally restored, allowing many interfering noises to be removed even before it is converted to digital sound.

#### 4.3.3.4 Digitization of analogue magnetic audio tracks

Because the same carrier material is used as for the film, the chemical disintegration issues are the same. Cellulose acetate-based sepmags are prone to the vinegar syndrome while polyester is far more stable. Experience has shown that the iron oxide has a negative impact on their condition and promotes the vinegar syndrome. This is also the case if an audio element on a polyester medium is stored in the same film canister as a cellulose acetate-based film element. Magnetic audio elements should therefore always be stored separately from picture elements. This is of course not possible in the case of commags because the sound stripe is glued onto the film and cannot be removed. In this case, managing the ambient storage conditions is the only way to slow down disintegration [▶ IASA TC-04].

#### 4.3.3.5 Selecting the audio track for digitization

If different elements with the same audio track are available for digital preservation, the following recommendations will serve as a guide to select the most suitable element to digitize. These are general assessments of the quality aspects which should always be re-checked in each individual case due to possible damage. Tests should also be conducted to find out which element is the best quality. In these examples, the assumption is that all elements contain the same final mix of the identical audio track.

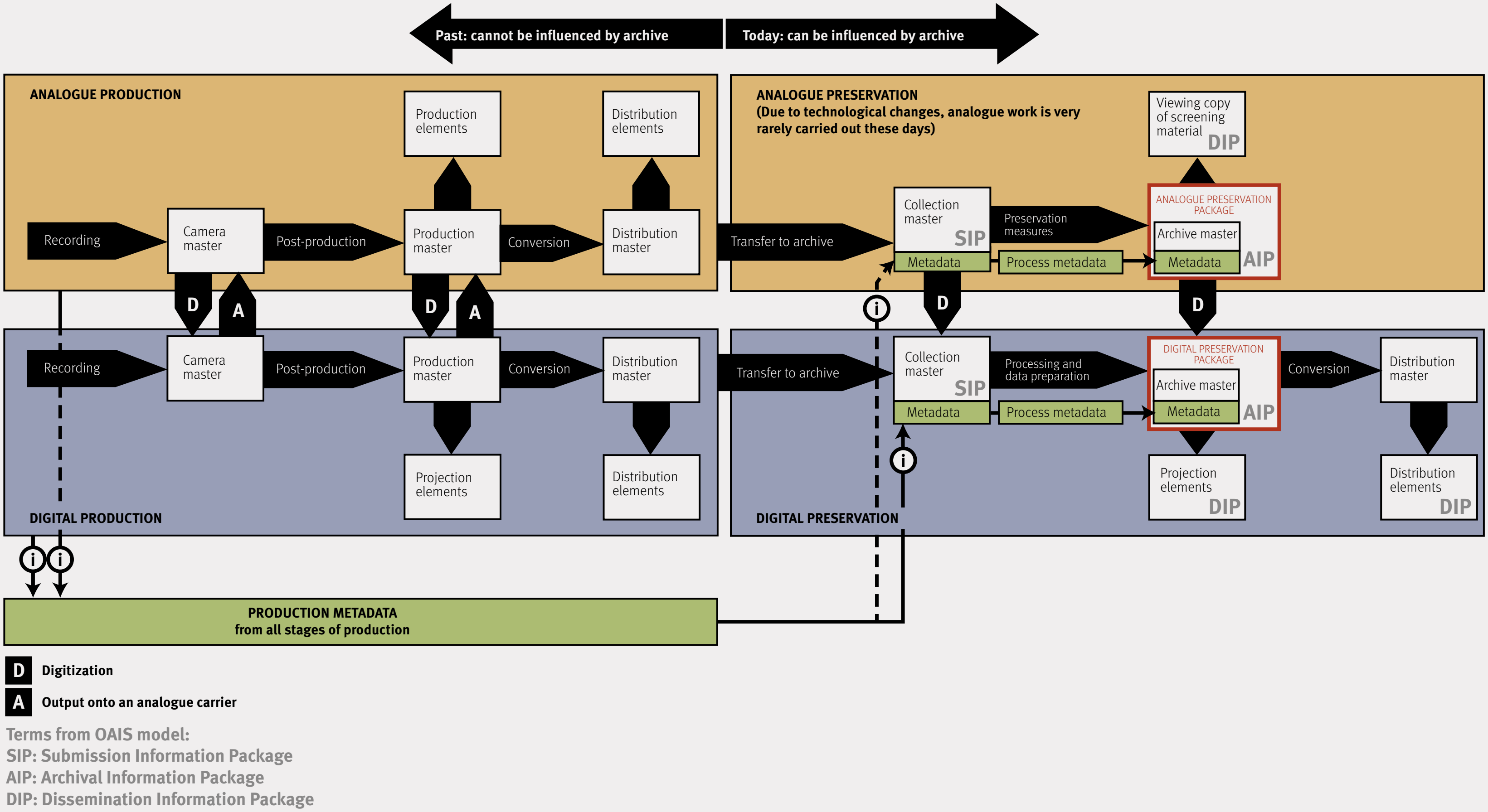



**Fig. 17: Video workflow.** Overview of video processes from recording to backup package for archiving.

- If there are two analogue optical audio elements with identical content, one in a small gauge format (e.g. 16 mm) and one in a wider film format (e.g. 35 mm), choosing the wider one is recommended.
- Generally, magnetic audio tracks are considerably better quality than optical audio tracks which have a more limited frequency range. A sepmag or commag audio track should therefore be given preference over an optical variant.
- If a complete recording is available in the form of separate sepmag tracks from post-production, the final mix can be digitally reproduced in excellent quality. However, this kind of reconstruction is labour-intensive and should, whenever possible, be produced with an existing audio track with the final mix as a reference.

### 4.3.4 Additional comments on film digitization

Film has specific characteristics that need to be considered during digitization in order to create digital material that is as true as possible to the original. This requires a broad knowledge of filming, production and projection technology. Five aspects of this are briefly covered here.

Several types of 35 mm film have been used with camera negative aspect ratios of 1.33:1 and 1.37:1. From the 1970s to the 1990s, 35 mm film with aspect ratios of 1.37:1 and 1.66:1 was used, but was often only projected and distributed at 1.66:1. It is desirable that the negatives, the intermediate format (intermediates) and the projection prints are all retained at the original aspect ratio, otherwise a part of history will be distorted for future generations.

In the field of analogue film, there are also a variety of «color spaces». These are dependent on the different chemical coloring processes used when color film is being developed. One example of this is Kodachrome reversal film, which was produced between 1935 and 2009 and was frequently used for small gauge films. It covers a spectrum of colors different to that of Eastmancolor film or Fujicolor film, for example. The different color spaces of various film types must be taken into account during the digitization process so that they can be suitably reproduced.

In the early years of cinema, projectors predominantly used carbon arc lamps. In the 1960s these were replaced by xenon lamps, which are still commonly used in today's digital cinema projectors. These have a cooler color temperature, so they produce a bluer picture.

This difference is particularly noticeable in colored silent movies intended for projection with carbon arc lamps. This factor should be taken into account in color grading of the projection element.

In small gauge film, almost anything goes! Amateur and experimental film makers have ceaselessly sought new solutions and there are masses of special technical characteristics to understand before any attempt to digitize such film appropriately.

Optical sound is a means of recording and reproducing sound using an optically readable soundtrack. Historic optical sound exists for mono and various stereo and multi-channel processes, including several that are digital. Analogue mono optical sound cannot be digitized correctly using a stereo reading head. This leads to severe distortion, particularly in the case of single-sided variable area sound recording, because the soundtrack and the reading head do not match. Special scanners and players are needed to digitize magnetic tapes used for film production. In contrast to an optical scan of optical sound, the reading head has to touch the magnetic strip to produce the best result. This means additional mechanical pressure on the tape each time it is read, but also that any physical deformation of the audio tape as a result of deterioration can impact greatly on the quality of the reading process.

When considering which area of the film surface should be projected onto the screen the answer may seem obvious at first. Due to the many projection formats that exist and the technical concomitants of film production the matter is, however, more complex than one may think. There were fewer options with analogue video and its reproduction on TV than with film, but with the introduction of digital video and the option of playing videos on TVs as well as on computer screens with a player, the question has become very complex. The complexity is the result of the variety of formats and image aspect ratios as well as the fact that even with normal reproduction on TV or screen projection, part of the image is not visible. Film and video are mixed up with each other as they can be transferred in the same way. If a film is to be read and displayed on TV or in a cinema, the image frame that will finally be visible to the viewer must be considered at every point of the production process. The same question arises when the film is transferred for preservation purposes.

In classic film projection, the film travels through the film gate. The film gate limits the area of the light beam that is cast through the film and onto the screen. The dimensions of the film gate and the position of the film in front of it therefore define the parts of the film surface that are visible in projection. Generally speaking, the image frame on the film is defined by the format that is used. To ensure that only the image and no other part of the film is visible, the film gate is slightly smaller than the width and height of the image frame. For clean image edges, the projected image is cropped once more on the screen as well. The area that is cut off may be up to 5 % of the image but has never been clearly defined in a standard.

### 4.3.5 Video from recording to archiving

[Fig. 17].

### 4.3.6 Additional comments on video digitization

Video has specific characteristics that need to be considered during digitization in order to create digital material that is as true as possible to the original. This requires a broad knowledge of recording, production and screening technology.

If working with a service provider, he must be prepared to provide you with details of his equipment and explain and discuss the signal paths and procedures they use, and this should form part of a work contract. It should also be possible to view their facilities – the details on their website will not usually be sufficient. A few special features are highlighted below that need to be taken into account and if necessary discussed with a service provider when digitizing video material.

It's always best to avoid any loss of quality during digitization, as this can only superficially be corrected using digital means later on. For digitization purposes tape decks should be used that will get the best out of the remaining analogue signal. Considerable technical progress will often have been made during the lifespan of a video format, giving rise to a noticeable reduction in image noise and improvements in resolution and image stability, even within the originally defined format specifications. So latest generation equipment is usually most suitable, particularly if it has had fewer operating hours (especially the video heads) and has been maintained either regularly or recently. Some machines with few operating hours may have deteriorated if they have not been used for a long time. As a rule, it is better to use professional industrial equipment rather than consumer devices, but only within a certain period of its date of manufacture and only if it is a recent model. For Video 8 / Hi8 formats and VHS tapes, the best consumer devices of the latest generation deliver visibly better picture quality than professional equipment of the same format that is 15 to 20 years older and cost several times as much. It may be worth making a critical visual comparison of image quality on the devices available if the budget precludes buying in any new or second-hand equipment.

If the video tapes are very old, tracking control should be carried out very carefully during the entire copying process, preferably by monitoring the FM signal from the video head or at least by measuring its strength using a suitable display.

Assuming the equipment is in good condition, if the tape squeaks or the picture is very unstable either horizontally or vertically, or the picture goes snowy, the tape is showing signs of age damage and will need treating before it can be digitized. This may be fairly time-consuming but, as a general rule, the information will still be present on the tape at a sufficient magnitude to be read, but the physical properties of the tape surface will be hindering or preventing it from being played. Provided the surface layer has not separated from the substrate, there is every chance that the tape will still be playable.

Even if a video tape shows no external signs of ageing, it should be run through a cleaning machine (known as a tape evaluator) before it is digitized. As well as cleaning the tape, this machine also smooths the surface of the tape. (It does this using an integral sapphire blade that does not, as its name might suggest, scrape away the surface, but actually polishes it with its rounded edge.) The manufacturer RTI supplies suitable evaluators for U-matic, VHS and Betacam tapes. It takes a few minutes to clean each tape; although tape evaluators can cost almost as much as a small car, it is worth taking a look at the price of getting tapes cleaned.

When restoring video material, signal integrity should be maintained for aesthetic reasons. This precludes the use of digital masking or scaling, which can be used to conceal the flickering side edges or visible head changes at the bottom of the picture; these are perfectly valid, although they were previously less visible due to the edges of the CRT monitors casing. Signal integrity also prevents the picture being de-interlaced by converting it to progressive scanning. This would result in unsightly «combing» or interlace artefacts appearing during movement. These should not be suppressed by halving the vertical resolution by only including every other half frame. When digitizing, the lateral picture position should be set so that the (analogue) image is precisely centred in the digital window at all times. In many analogue productions, the lateral position can be seen to jump from scene to scene. Time-consuming digitization would take account of this and attempt to correct the lateral jumping, but this would require several iterations. These jumps are unique technical defects resulting from the production process and in this sense they are historical, although not necessarily worth retaining!

Similarly, any cropping, panning, compressing or stretching to adapt the old 4:3 aspect ratio to the current 16:9 format would constitute an inadmissible change to the images. Dark bars on the narrow sides of the new picture are acceptable – they bear witness to cultural and technological change and must remain reproducible. This applies both to digitization and also any usage (such as projection, screening or editing). The archive master that is to be preserved long term should not only retain the original aspect ratio, but also the original number of lines per frame or half-frame.

Any direct extrapolation would violate the integrity of the signal. The same applies to the number of pixels in genuine digital sources when they are read in.

A time base corrector (TBC) is usually essential for stabilizing analogue video images, as many analogue to digital converters, especially professional ones, struggle to process unstable signals and may omit or freeze images, for example. For very old formats (open reel) or U-matic tapes from the 1970s edited without color locking, you may need to use two TBCs simultaneously: an old one that can handle historical instabilities (larger tolerances in signal timing and phase transition in the color subcarrier), and a modern one that frees the color signal from moiré distortion and adapts the signal from the historical TBC, which may still be too unstable, to the tight tolerances of the A/D converter.

After digitization (strictly speaking, after TBC output), it will no longer be possible to correct lateral deviations (jitter), fluctuations or any other type of instability because they will have become part of the picture content, which is underlaid with the new, stable synchronizing signals. Choosing the correct TBCs is therefore of paramount importance, and calls for considerable knowledge and fact finding. Depending on the signal that requires stabilizing, a suitable historical TBC may be needed, but this advice should not be misconstrued as a universal panacea.

Huge technological progress has been made in this field too, which will have an impact on the image structure. So: only as old as necessary, otherwise as modern as possible.

TBC settings (brightness, contrast and color saturation) should be used with knowledge and caution. On no account should an old grey picture with weak colors be tuned to the modern contrasts with which we are familiar in digital media. A sound knowledge of works and documents from all epochs of electronic imaging is vital in order to adjust the settings in an historically appropriate manner. However, modest adjustments within the scope of what is technically possible and the usual contrast range for the video channel may be useful. A wave form monitor would be needed for this purpose so as to visualize and interpret the video signal. When adjusting the contrast and brightness, it is important to make sure that no part of the signal is cut off, particularly the highlight areas or the noise components near the black level. This would cause them to be irretrievably lost, which is completely unacceptable, even if the picture appearance is purportedly improved. There is also an argument for increasing the contrast – reducing it would never make sense – since very soon even old video images will only be viewed using flat screens or projectors, and this equipment does not have any real means of correcting brightness or contrast, unlike the former CRT monitors that could be adjusted quite amply to suit the material being screened.

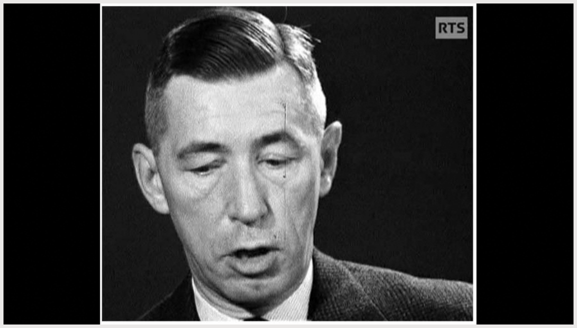
These comments relate to video material that has not been produced using professional equipment and suitable studio lighting, and for which the signal has never met the standards that have in principle applied for decades now and that would make it possible to readily screen the material on a modern display.

If any adjustments are made to the contrast or brightness, these should be done cautiously and responsibly, without necessarily exploiting the boundaries of what is technically possible. The traces of lacking technical perfection when the material was created should not be obliterated here – they belong to the historical substance of the source. They should also be suitably documented using examples (screen shots of the wave form monitor with and without corrections, or a video file of brief excerpts with and without the corrections; however, noting down the numbers on control knobs is pointless). Provided none of the signal is reduced, any adjustments can be reversed using this documentation.

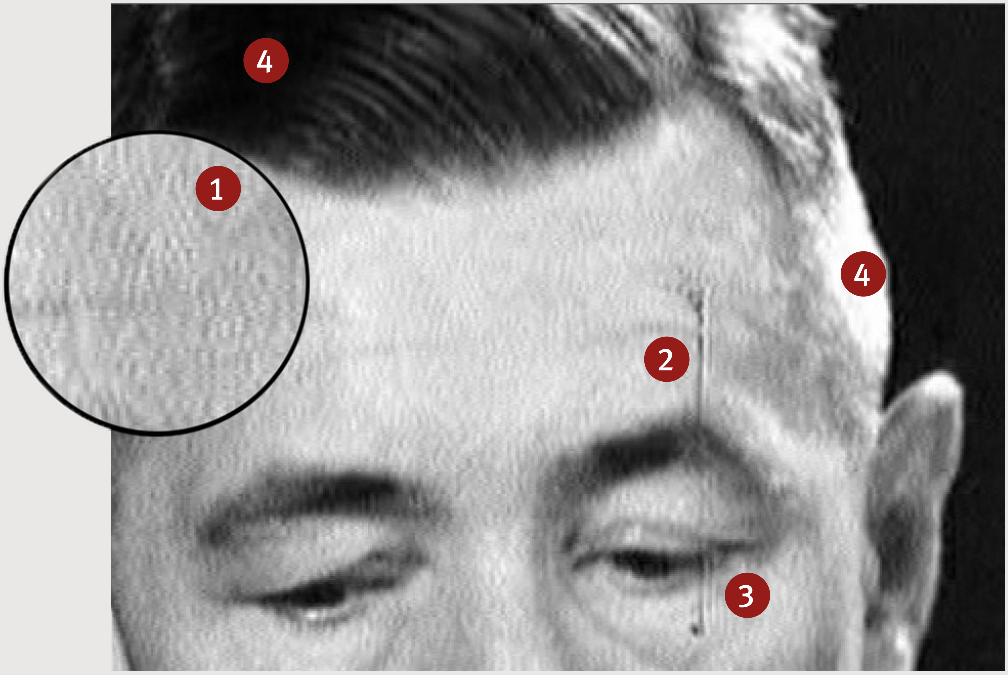
Original medium:
16 mm B&W reversal film

First transfer medium:
Betacam SP, SD PAL 50i

Second transfer medium:
Digitization in H.264, HD 1080 p




The transfer from the original 4:3 aspect ratio of the 16 mm film to 16:9 format has resulted in black bars on both sides of the picture. In the figure above, the 4:3 picture is shown in a narrow white frame for clarity.




Picture: Radio Télévision Suisse

1) Structural artefacts caused by a combination of film grain, the linear structure of the analogue video and digital scaling plus compression. Motion artefacts (not shown here) caused by the unfortunate influence of film grain on digital compression.
2) Artefact from the original material: scratch.
3) Artefact caused by artificial re-sharpening during sampling in SD.
4) Loss of picture information in the lightest and darkest parts of the image due to the reduced aperture range of the transfer in SD.

In color film, you also get color shifting due to the change in the color space, and poorer color reproduction as a result of digital data reduction in the color channels.

**Fig. 18: Example showing the consequences of multiple media transfers.**

If a playback device has an integral TBC that can be bypassed, the results oft the integral TBC can be compared with the ones of an external TBC. If the integral TBC also has a noise reduction option, critical comparison with an external model may be worth it as well.

Since the option of reducing noise has existed for video, it has been the subject of some controversy. In audio it has for a long time been common practice not to use any sort of filter during digitization, but instead to use filters subsequently, depending on the purpose. In video, storage space was previously too expensive and it was too time-consuming to create raw digitized material without noise reduction, with the option of processing this later. The argument against noise reduction is the maxim of signal integrity, since any reduction in picture noise will also change or weaken picture details, which would then be irretrievably lost. In favour of noise reduction is the fact that some of the noise is the result of multiple copying processes during the tape's lifetime, and reducing the noise would bring the result closer to its original appearance. If the content is going to be distributed on a DVD with a high degree of compression, for example, noise reduction will actually be necessary to avoid any unsightly compression artefacts. Until now, the time-consuming nature of any subsequent processing and the high storage costs (at least twice the price) has usually resulted in a decision being made prior to digitization.

If noise reduction is to be carried out, a modern, high-quality TBC should be used that will also be able to rectify distracting drop-outs relatively effectively. Since television and the video industry have switched to HD, SD equipment can often be procured at favourable prices. This enables you to reduce the noise by varying degrees. But despite the temptation, this facility should be used in moderation only.

If funding is sufficient to include raw digital material, hardware or software can be used at a later date to reduce noise. The TBS 180/185 model TBC from Snell & Wilcox has a digital input and output, and its drop-out compensation also works with a pre-digitized signal from a HDD (output via the SDI connection, of course), unlike all the older drop-out compensators that only work with an analogue source, and usually unsatisfactorily at that! Using two computers each equipped with an A/D converter, you can achieve perfect drop-out compensation at a later date in real time with no conversion losses (thanks to SDI) at a fraction of the cost of digital video restoration software and hardware. As an alternative to this admittedly unconventional solution, if funding is in short supply you could use a noise-removal plug-in (e. g. Neat Video) for popular digitizing applications such as Premiere and FinalCut. Processing time may end up being higher and productivity may therefore fall. The algorithm for drop-out removal also seems to be less powerful. Note that drop-out removal functionality is linked to noise reduction.

If you use this approach, you will absolutely need to use uncompressed digitization at 10 bits or more. This is to be recommended in any case these days because raw digital material, whether it is filtered or not, is frequently used to create multiple derivatives – archive files, slightly compressed commercial or demonstration copies, and highly compressed streaming format for internal use or distribution on the Internet. You should design a suitable workflow that permits you to create the appropriate derivatives either shortly after digitizing or at a later date.

The decision as to whether to create compressed or uncompressed files for archiving depends on the context (including data volumes, significance and available funding) and also on the original quality of the material. However, contrary to what might be expected, noisy pictures are problematic for compressors because noise is unpredictable «information» and compression is based on predictable repeating image structures.

So paradoxically, a very noisy, jittery VHS tape cannot be compressed as much as a Betacam SP tape recorded with professional lighting and a tripod (assuming the historical significance of their content is comparable).

When deciding whether to compress or not, in addition to the aspects already mentioned you should also consider long term preservation arguments regarding file formats. Uncompressed data performs better in this respect.

### 4.3.7 Data retention models

Storage devices cannot store data entirely without errors. This does not usually have serious consequences for analogue storage, depending on how frequently and where the errors occur. For this reason, the firmware in these data storage devices constantly checks to ensure the data is correct, and fixes the data itself when necessary without users noticing. But the algorithms used by the firmware can only rectify a limited number of faults. If this limit is exceeded the devices fail and must be replaced (ideally before this happens). In this respect, current HDDs with a capacity of up to 2TB are somewhat more secure than HDDs with a higher capacity [▶ Section 4.3.8].

If redundant storage is used (e.g. RAID architecture), the data held on a failed storage device can be restored, otherwise you will have to resort to a backup copy. If no backups exist, the data will be lost.

In addition to the suitability of its format, storage redundancy is an important factor. The more copies that exist and the greater the redundancy of information within each copy, the greater the likelihood of it being retained long term. The «3-2-1 rule» sums up this situation very succinctly: for important files, you should store three copies on two different types of storage device, with one copy off-site, in other words physically remote from the actual archive.[3] The choice of storage media and their physical separation also determine how secure they will be.

Redundancy, duplication and monitoring are therefore cornerstones of digital archiving. It is worth comparing several quotations and obtaining independent opinions for setting up an IT structure in an in-house archive and also for storing archived data externally. Memoriav can act as a mediator in such cases.

### 4.3.8 IT Infrastructure

Device drivers and operating systems are subject to short development cycles, just like the rest of the IT industry. A lack of software support can make fully functional hardware obsolete from one update to the next. At a hardware level, the simple lack of a particular connector cable and interfaces not infrequently prevents devices from being connected. Interfaces between playback equipment and controlling computers are changing constantly, often making it difficult to connect an old reading device to a modern computer. It is therefore necessary to monitor software and hardware trends and react appropriately to new developments.

Although methods such as emulation and command line instructions offer ways to overcome these problems, they are very time-consuming and require highly specialized know-how. Close institutionalized cooperation between IT management and archive management when planning and managing digital archive systems is therefore a prerequisite for long-term solutions.

3 Peter Krogh from the American Society of Media Photographers; find additional information here: http://dpbestflow.org/node/262#321 [1.10.2019]

For this reason, you should pay attention to prevalence, longevity and long-term support by the industry not only when selecting file formats [▶ Format evaluation table in section 5.2], but also when choosing an IT environment (equipment, interfaces, operating system and drivers).

Although methods such as emulation and the use of command line controls do represent ways of overcoming these problems, they are very time-consuming and can only be carried out by IT specialists, which will be very costly. Close institutionalized cooperation between IT and archive management when planning and managing digital archive systems is therefore a prerequisite for long-term solutions.

For archiving files, combined storage both on servers or HDDs and also on a tape-based IT storage medium such as LTO (Linear Tape-Open) is recommended, as well as storing copies in different geographical locations. LTO is supported by a broad-based consortium. The consortium has finalized a roadmap for future developments, with these developments being defined and communicated several years in advance.

LTO tapes are readable two generations back and writeable one generation back.

But there is still a problem in that the formatting of these tapes is not standardized. Tape archiver formatting (TAR) is open source, but it makes accessing individual files cumbersome because you have to unpack the directory and the content first. If the directory is damaged, it may be impossible to access the files. In general, slow access times and the fact that they have to be accessed sequentially are disadvantages of IT tapes. The Linear Tape File System (LTFS) was introduced with generation 5 of LTO. This is also an open-source method of formatting tapes, which considerably increases the compatibility of LTO and can be recommended for archiving purposes. LTFS enables the contents of an LTO tape to be processed in the same way as those of a HDD.

None of the storage media mentioned is intended for long-term storage on the shelf. Hard disk drives and tapes are swappable elements in the infrastructure of an archive system. Ideally, they are stored in a library system with automated processes to check for readability and bitstream preservation and which also enables any faulty storage media to be easily recognized and replaced. If only a small number of tapes is used solely for backup purposes and then used only rarely, these library functions are not necessary.

Even though the critical data quantity that would justify the acquisition of a library system is in practice not always reached, and the question about appropriate handling and (medium-term) storage conditions therefore arises, the issue of obsolescence plays a far more important role (apart from readability, as mentioned). Or to put it differently: If the tapes are not exposed to extreme or completely unsuitable conditions, they will have to be migrated before preservation damage occurs due to the reading devices becoming obsolete. As regards digital archiving, these unavoidable migrations (preservation planning) are therefore more crucial than the physical storage conditions.

### 4.3.9 File sizes and file systems

Digital audiovisual material usually consists either of one huge file (held in container files) or an extensive series of smaller files (as individual images). When dealing with both types of files, the limits of common operating systems are frequently reached because the file sizes and the number of files per folder are restricted depending on the file system. The latter also depends on the operating system used.

With an overall storage volume of up to 2.2 TB (and files up to 4 GB), no major problems can be expected. If larger data volumes/files need to be managed and therefore need to be addressed with more than 32 bits, a variety of different incompatible solutions have developed.

HDDs on computers running under Microsoft operating systems generally use the FAT32 (32 bit) or NTFS (32 bit or 64 bit) file system. Macintosh uses its own Mac OS (Extended) file system, also known as HFS+ (64 bit). These file systems enable the computer to recognize and point to external HDDs. Read and write permissions are influenced by a combination of the operating system and the file system.

Copying files using «drag & drop» or «copy & paste» is a source of write errors; in everyday use these errors are not significant, but when dealing with very large data volumes (either very big files or lots of individual files), they can be important. Copy processes carried out at a lower level within the operating system (command-line level on the input console) are less prone to errors than those in applications that have a graphical user interface. For example, the «cp» command line function copies the data located within a file perfectly but does not copy the file itself, whereas the «gcp» or «ditto» function copies both. You should always use a check sum utility such as MD5 or SHA-1 for security and for checking file integrity [Section 5.3.3].

#### 4.3.9.1 Microsoft operating system

Maximum file size:
FAT32: Maximum file size is 4GB
NTFS: No limit for file size
Maximum number of files per folder:
FAT16: 512
FAT32: 65,534 files or folders per folder
NTFS: 4,294,967,295

#### 4.3.9.2 Macintosh operating system

Maximum file size (dependent on operating system):
Mac OS X v10.3–10.5.2: 16 TB
From Mac OS X v10.5.3: almost 8EB
1 EB = 1 Exabyte = 1,000,000 TB = $10^{18}$ Bytes
Maximum number of files per folder:
HFS/HFS+: 4,294,967,295 files or folders per folder

## 4.4 Ethical issues

One of the core tasks of heritage institutions is preservation, in other words maintaining documents/works in the form in which they were delivered. This core task conflicts with other core tasks such as usage. For example, if you keep a roll of film permanently frozen at –20° C, you are almost certain to preserve it long term. But although it's preserved, it is not usable, and its content cannot be viewed.

Preserving it is pointless, its purpose remains unfulfilled, the effort expended is difficult to justify and it will be virtually impossible to obtain the necessary funding if the film cannot be viewed.

This conflict between preservation and usage is intensified in the case of analogue material, since this wears away each time it is used. If you are striving to achieve the ideal of presenting a work as it was seen at its première and/or the time it was first interpreted, you come up against even more of a contradiction – maintaining the material in its current condition and presenting it in its original condition. Heritage institutions must therefore find a reasonable compromise between the following factors:

- Current condition
- Knowledge about original condition
- Potential modern technical possibilities

All reproduction technology generates technical artefacts that merge into the content when a document or work is created. At the time of recording and also later, these artefacts are perceived ambivalently. They are often seen as flaws, sometimes as an important part of the creation (e.g. as a style or «statement»), but almost always as a conscious or subconscious means of chronologically dating a document/work. Any transfer from one form to another, be it analogue to analogue, analogue to digital or, depending on the process, even digital to digital, will once again leave a mark on the work as a technical procedure.

To prevent any serious negative or uncontrolled impact that digitization might have on the aesthetics of a work and to enable sensible decisions to be made regarding any changes to the format of documents, you should therefore be clear on a few points:

- Digitization changes the quality of a document or work, the options to present it and how it will be perceived.
- Digital material will necessarily be perceived differently when it is digitally reproduced compared with the analogue original reproduced in an analogue manner.
- Digital artefacts blend irretrievably with analogue artefacts and it is usually not possible to distinguish between them visually. In-depth analysis is complex and its results are of limited use.
- Poor digitization will have an extremely negative impact on the aforementioned points [▶ Fig. 18].

It is important to be familiar with the typical properties of analogue source media and also those of potential digital target formats in order to plan sensible processes and be able to document the original and heritage contexts appropriately. The following basic questions should be asked, particularly for documents of an artistic character, and answered in a project-specific context:

- Should modern technical methods be used to make more of the original material than was possible at the time it was created?
- To what extent should surviving creators or former decision makers influence restoration? What impact should the current opinion of the artist or author have?
- What do you do if you can now, with the aid of the source material and current technology, deliver something that the artist originally wanted but was not (fully) able to create?
- To what extent should restoration be influenced by how and with what quality the work has been received over the years?

There are no wholesale unambiguous answers to these questions. Differing ways of visualizing old documents today have led to heated debates at all levels regarding what is ethically acceptable and what is not. Defining clear guidelines is often made even more difficult by the fact that interventions can be carried out at subtly differing levels of intensity.

Three basic principles, which are embodied and expanded in the excerpts from standards shown in section 4.4.2 below, should be provided here for guidance.

- There is a greater likelihood that the integrity of a work will be retained.
- All the processing options that existed prior to an intervention still exist afterwards.
- Each processing step is carefully documented.

### 4.4.1 Restoration vs. recreation

When historical films or videos are re-published, they are frequently referred to as a «restored version». This term is often used after interventions that clearly exceed the ethical limits of restoration, for example, cropping the picture so a work can be transferred from an aspect ratio of 4:3 to 16:9, the automated coloring of black and white films and the use of non-contemporary sound tracks for classic silent movies. The terms restoration and recreation have been coined to distinguish between processing that falls within ethical limits and that which does not. Recreation is applicable in cases where the ethical limits described have been exceeded and a new work has been created that is similar to the original.

Since it is usually very complex to assess whether the processed version of a work is a restoration or a recreation and since it is difficult to determine the boundary between the two terms, the decision will depend on the context, but guidance should be sought from the standards that are available [Section 4.4.2].[4]

### 4.4.2 Ethical standards

The various national and international professional associations for experts in heritage institutions have agreed standards in their ethical codes that can also be used for reference in digitization projects.

The following excerpts are relevant to the digital archiving of film and video:

– VSA/ICA: «[…] Archivists should protect the integrity of archival material and thus guarantee that it continues to be reliable evidence of the past. The primary duty of archivists is to maintain the integrity of the records in their care and custody. […] Archivists should protect the authenticity of documents during archival processing, preservation and use. Archivists should ensure that the archival value of records, including electronic or multimedia records, is not impaired during the archival work of appraisal, arrangement and description, or by conservation and use.»[5]
– AMIA: «[…] To restore and preserve artifacts without altering the original materials, whenever possible. To properly document any restoration/preservation decisions and to make decisions consistent with the intentions of the creators, whenever appropriate. To balance the priority of protecting the physical integrity of objects/artifacts with facilitating safe and non-discriminatory access to them. […]»[6]
– IASA: «[…] sound and audiovisual recordings and associated materials (including original carriers) shall be treated with appropriate respect, and mishandling by unskilled operators should be avoided. They need to be conserved according to the latest technology to minimize deterioration. Their original content and physical representation shall be safeguarded from being modified, truncated, extended, falsified or censored in any way. Archivists' obligations also include the permanent care of accompanying materials (photographs, notes, etc.) and the handling of the description of the contents of the recordings (for metadata, catalogues and discography, and other publications).
[…] Any kind of preservation, restoration, transfer and migration and of sound and audiovisual content should be done in such a way as to avoid or minimize the loss of data and other relevant information on the original recording. In addition, ancillary information, which may be part of the original sound or AV document (i. e. content and carrier) in manifold forms, should be safeguarded. The original carriers should be preserved in usable

4 See also Edmondson, Ray, *Audiovisual Archiving: Philosophy and Principles*, p. 62, https://bangkok.unesco.org/content/audiovisual-archiving-philosophy-and-principles [9.9.2019]

5 VSA code of ethical principles for archivists, https://vsa-aas.ch/beruf/ethikkodex/ [9.9.2019]; the VSA code equates to the German version of the code of ethics published by the International Council on Archives ICA

6 AMIA, *Code of Ethics*, https://amianet.org/wp-content/uploads/AMIA-Code-of-Ethics-DUPE.pdf [9.9.2019]

condition for as long as is feasible. This also applies to all digitized materials, since the technology and methods of signal extraction and analogue-digital-transfer are still subject to further development, and original carriers – and packaging – often provide ancillary information.
[…] Transfers made from old to new archive formats should be carried out without subjective signal alterations. Any kind of subjective signal enhancement (like de-noising, etc.) must only be applied on a copy of the unmodified archival transfer (e. g. on access copies, see TC03, chapters 7–8).
All preservation actions, restoration, transfer and migration processes (including long-term digital storage procedures), should always be accompanied by careful documentation, in order to provide all relevant specifications that ensure the authenticity of the primary data and prevent the loss of primary, secondary, and contextual information constituted by the original AV document.
Technicians working in an archival preservation setting must ensure that they document any alterations of sounds and audiovisual data done for other specific purposes such as types of dissemination.
Technicians whose work involves the creation of information systems for cataloguing sound and audiovisual collections should also avoid data loss in those systems.
[…] The main technical aspects are that access should not do any harm to the physical integrity of the document and, on the other hand, the user should be given the possibility to access all the content relevant for the document.»[7]

- ECCO: «[…] The fundamental role of the conservator-restorer is the preservation of cultural heritage for the benefit of present and future generations. The conservator-restorer contributes to the perception, appreciation and understanding of cultural heritage in respect of its environmental context and its significance and physical properties. […] Conservation consists mainly of direct action carried out on cultural heritage with the aim of stabilizing condition and retarding further deterioration.
  Restoration consists of direct action carried out on damaged or deteriorated cultural heritage with the aim of facilitating its perception, appreciation and understanding, while respecting as far as possible its aesthetic, historic and physical properties.
  Documentation consists of the accurate pictorial and written record of all procedures carried out, and the rationale behind them. A copy of the report must be submitted to the owner or custodian of the cultural heritage and must remain accessible. Any further requirements for the storage, maintenance, display or access to the cultural property should be specified in this document.»[8]
- ICOM: «[…] 2.24 Collection conservation and restoration. The museum should carefully monitor the condition of collections to determine when an object or specimen may require conservation-restoration work and the services of a qualified conservator-restorer. The principal goal should be the stabilization of the object or specimen. All conservation procedures should be documented and should be as reversible as possible, and all alterations should be clearly distinguishable from the original object or specimen. […]»[9]
- FIAF: «Film archives and film archivists are the guardians of the world's moving image heritage. It is their responsibility to protect that heritage and to pass it on to

7 International Association of Sound and Audiovisual Archives (ed.) *Ethical Principles for Sound and Audiovisual Archives.* IASA Special Publication No. 6, 2011, https://www.iasa-web.org/ethical-principles [28.2.2018]
8 E.C.C.O. *Professional Guidelines,* http://www.ecco-eu.org/documents/ [9.9.2019]
9 ICOM, *Ethische Richtlinien für Museen von ICOM,* https://www.museums.ch/publikationen/standards/ethische-richtlinien.html [9.9.2019]

posterity in the best possible condition and as the truest possible representation of the work of its creators. Film archives owe a duty of respect to the original materials in their care for as long as those materials remain viable. When circumstances require that new materials be substituted for the originals, archives will retain a duty of respect to the format of those originals. […] 1.4. When copying material for preservation purposes, archives will not edit or distort the nature of the work being copied. Within the technical possibilities available, new preservation copies shall be an accurate replica of the source material. The processes involved in generating the copies, and the technical and aesthetic choices which have been taken, will be faithfully and fully documented. 1.5. When restoring material, archives will endeavour only to complete what is incomplete and to remove the accretions of time, wear and misinformation. They will not seek to change or distort the nature of the original material or the intentions of its creators. […] 1.7. The nature and rationale of any debatable decision relating to restoration or presentation of archive materials will be recorded and made available to any audience or researcher. 1.8. Archives will not unnecessarily destroy material even when it has been preserved or protected by copying. Where it is legally and administratively possible and safe to do so, they will continue to offer researchers access to nitrate viewing prints when asked to do so for as long as the nitrate remains viable.»[10]

As already mentioned in the three basic principles above [Section 4.4], documentation plays a central role in all conservation and/or restoration interventions and associated decisions in virtually all areas of professional ethics.

10 FIAF, *Code of Ethics*, https://www.fiafnet.org/pages/Community/Code-Of-Ethics.html [9.9.2019]

In a digitization context this means, for example, that all preparatory measures (cleaning, drying, etc.), practical implementation (the hardware, software and signal path used, etc.), and checking (check sums, visualizations, etc.) of digitized films or videos must be recorded and this documentation also retained for posterity.

In all ethical codes, the goal is to maintain the «substance» of documents and works without any interventions that are unnecessary or that deviate from the intentions or possibilities open to the creator, with preservation taking priority over restoration if there is insufficient funding for both. Substance is clearly understood to mean not only artistic value but also integrity, authenticity and archival value (evidence). Digitization necessarily goes beyond simple preservation and, as mentioned above, affects the «substance» and the way in which it is perceived.

Moreover, a document's integrity and authenticity can only be ensured after digitization by using reliable metadata, for example.

Originals should be treated as carefully as possible and, whenever possible, stored under suitable conditions that slow down deterioration. As already mentioned, this protection should be weighed against the aim of access and usability.

If circumstances call for originals to be replaced by copies, the original format and its properties should be respected, and originals should never be unnecessarily destroyed, even after digitization.

The previous sections of this document have examined the principles of film and video, and also issues relating to their digital archiving. The following chapter will now provide more tangible evaluations and recommendations.

## 5.1 Digital archiving in general

Dealing with analogue and digital audiovisual material correctly calls for extensive specialist knowledge and a specific infrastructure. This is all the more important if digitization and/or long-term digital conservation is to be carried out in-house. This therefore raises the question of the extent to which in-house skills and infrastructures can be expanded, what will have to be bought in as external services and where the staffing and financial limits lie [Section 4.1.1].

Many archives already have a solution for the digital archiving of administrative documentation, and are connected to cantonal archive servers, for instance. These are good preconditions, but remember that when you are dealing with audiovisual files, the data volumes are many times greater than those for typical administrative documents or text documents, particularly if the documents exist in recommended archiving formats. So integrating digital audiovisual material into an existing digital archive is often not a straightforward task.

The following points are important when clarifying what requirements need to be met [Section 4.1]:

1. Compiling quantitative and qualitative inventories (overall volumes, media and condition).
2. Identifying the items [Section 4.2 Identifying formats].
3. Appraisal of the the archive and prioritizing of preservation actions.
4. Preservation strategy:
   a. Choice of suitable target formats (archiving formats as well as copies for use).
   b. Choice of technical infrastructure for digitization and data preparation.
   c. Choice of storage solutions.
5. Indexing strategy: inherited and process metadata, technical and descriptive metadata, standards, etc.
6. Access and usage strategy: search tools and infrastructure for access and usage.
7. Developing an emergency plan including risk management. Reviewing the suitability of buildings and climatic conditions.
8. Financial plan (for digitization AND the continuing long-term preservation and maintenance of data).

The following should also be noted:

– The staff responsible must be given the opportunity to acquire basic skills and undertake continuing education and training. However, experts will need to be involved in the more detailed work (IT professionals, restorers, etc.).
– The requirements arising from long-term preservation should be decisive when making decisions. This applies not only to funding and staffing, but also to IT technology, which is subject to rapid and far-reaching change
– You should plan to set up the long-term preservation infrastructure in such a way that the archive can maintain its status quo even if there are short-term financial and staffing shortages. For example, company mergers and buy-outs can lead to archive documents being neglected.
– An emergency plan should exist for extreme events such as disasters and severe financial cut-backs.
– The existing long-term preservation strategy should be regularly reviewed and improved, since the technical infrastructure is subject to constant change.

- Agreement must exist on the extent to which archive material and collections within the heritage institution are likely to grow. Storage space, infrastructure and emergency plans must also be tailored to growth forecasts.
- Regular monitoring mechanisms are vital in order to safeguard quality. These include monitoring when material is received in the archive, monitoring during the processing of archive material and also the regular maintenance and checking of archive files.
- Access copies do not need to be stored based on the same requirements as digital archive copies for long-term preservation. Most importantly, they should be stored at a different location and be accessed using a different infrastructure, since they will be used more frequently and by different people.

If the above requirements and recommendations cannot be met internally, material that cannot be adequately cared for can be entrusted to specialist heritage institutions on a loan basis or as a gift. If this option is taken, access via digital access copies should be provided in the archive of origin. The original archive and the recipient archive must communicate actively regarding any measures taken and any changes affecting the transferred archive material. The access copies must be kept up to date accordingly. Formats that cannot be processed in house must be handed over to external service providers for processing. Memoriav can provide assistance with such transactions.

## 5.2 Evaluation of common file/video formats and data storage carriers

File formats and data carriers play an important role in maximizing the life of documents. The following evaluation of file, video and carrier formats has been drawn up by the Memoriav cross-sectoral working group and reviewed by the Memoriav Video Competence Network. Its focus is on archivability and suitability for long-term storage, and it therefore only relates to archive copies, not copies for access or other usage; the requirements for the latter differ from those for archive copies.

The evaluation is based on the criteria of the NESTOR competence network for the long-term preservation and availability of digital resources in its handbook: A brief encyclopaedia of long-term digital archiving.[11] The requirements specified in this handbook not only apply to digital reproductions, but also to digital and digitized documentation and metadata

The codecs listed in this table are already used in heritage institutions. Other codecs applying lossless compression but are rarely or never used in an archival context in Switzerland (e. g. HuffYUV and Lagarith) are not examined further here. The codecs are given one of three ratings:

Recommended: Based on NESTOR criteria, material can be preserved for future use with no restrictions.

Conditionally recommended: Prevents certain options for future use, but is conditionally recommended for the reasons stated in each case.

Not recommended: Prevents important options for future use and migration, specifically: lossy compression, proprietary, non-standardised, possible obsolescence or unsuitable data carriers.

11 Published by H. Neuroth, A. Oßwald, R. Scheffel, S. Strathmann, K. Huth, *nestor Handbuch: Eine kleine Enzyklopädie der digitalen Langzeitarchivierung*, S. 147 f., http://nestor.sub.uni-goettingen.de/handbuch/nestor-handbuch_23.pdf [9.9.2019]

| Category | Formats | Data rate | Work area | Suitability for archiving | Comments |
|---|---|---|---|---|---|
| Individual images (only for film) | Uncompressed TIFF (16 bit linear) | | Recording, post-production, archive | Recommended (without layers) | Widely used, standardized, uncompressed; TIFF in 8 bit lin does not offer sufficient resolution for color depth and, today, in light of processing and storage capacities, is no longer worth being recommended as a compromise |
| | TIFF LZW compression | | Recording, post-production | Conditionally recommended | Compressed, possible compatibility problems between different software versions |
| | DPX (10-bit, 12-bit, 16-bit) | | Recording, post-production | Recommended | Widely used, uncompressed, industry standard; there are many variations/ subcategories |
| | JPEG 2000 | | Post production, distribution, archive | Conditionally recommended | CPU-intensive, not yet widely used, not fully licence-free |
| | JPG (scalable intra-frame compression) | | Recording, post-production | Not recommended | Lossy compression |
| Video codecs | DV (SD only) | 25 Mbit/s | Recording, post-production | Conditionally recommended | Recommended conditionally as widely used by amateurs and semi-professionals as a production format |
| | MPEG IMX (MPEG-2, SD only) | 50 Mbit/s | Recording, post-production | Conditionally recommended | Recommended conditionally as widely used in TV |
| | DVCPro50 (SD only) | 50 Mbit/s | Recording, post-production | Conditionally recommended | Not widely used, proprietary format (only supported by Panasonic) |
| | DVCPro100 (HD only) | 100 Mbit/s | Recording, post-production | Conditionally recommended | Not widely used, proprietary format (only supported by Panasonic) |
| | 10 bit-4:2:2-uncompressed (e.g. v210) | SD: 207 Mbit/s HD: 1,04 Gbit/s | Post-production, infrequent distribution, archive | Recommended | Low impact on visual quality despite considerable data reduction due to color subsampling, [Section 3.2.3.2], used mainly by museums. v210 is an Apple codec that may not be entirely lossless depending on the container (QuickTime, for example, uses the first bit for synchronization) |
| | 10 bit-4:4:4-uncompressed (e.g. v410, HD only) | 1,56 Gbit/s | Post-production, infrequent distribution, archive | Recommended | As for HDCam SR |

| Category | Formats | Data rate | Work area | Suitability for archiving | Comments |
|---|---|---|---|---|---|
| | 8 bit-4:2:2-uncom-pressed (e.g. YUY2 or 2yuy) | SD: 165 Mbit/s HD: 830 Mbit/s | Post-production, infrequent distribution, archive | Recommended | Low impact on visual quality despite considerable data reduction due to color subsampling [Section 3.2.3.2] but not widely used |
| | H.264 /AVC (Advanced Video Coding) | variable | Post-production, distribution | Not recommended | No single standard; see supplementary notes below |
| | H.265 / HEVC (High Efficiency Video Coding) | variable | Distribution | Not recommended | Standard exists, much more efficient compression than H.264 |
| | Apple ProRes | SD: 30–62 Mbit/s HD: 100–250 Mbit/s | Post-production | Conditionnaly recommended | Variations in descending order of quality: 4444 XQ, 4444, 422 HQ, 422 standard, 422 LT and 422 proxy); Apple proprietary format, bitstream and SMPTE decoding information dis-closed; conditionally recommended for native ProRes files only |
| | Apple ProRes RAW | variable | Recording | Conditionally recommended | Used in cameras and film scanners; conditionally recommended for native ProRes files only |
| | CineForm RAW | variable | Recording | Conditionally recommended | Used in cameras and film scanners; conditionally recommended for native CineForm RAW only |
| | XDCam HD (MPEG-2) | 50 Mbit/s | Recording, post-production | Conditionally recommended | Conditionally recommended because it is a standard recording format at TV stations and therefore very widely used |
| | FFV1 (from version 3) | variable | Archive | Recommended | Explicitly developed for archiving pur-poses lossless compression codec |
| | Avid-Codecs (DNxHD) | SD: 146–186 Mbit/s | Post-production | Not recommended | No single standard, different Avid codecs available, Avid proprietary format |
| | REDCODE RAW family, closely related to JPEG 2000 (HD only) | HD: 224–336 Mbit/s | Recording | Not recommended | Long-term compatibility uncertain |

| Category | Formats | Data rate | Work area | Suitability for archiving | Comments |
|---|---|---|---|---|---|
| Container (video) | MJPEG2K (Motion JPEG 2000) | n. a. | Archive | Not recommended | Explicitly developed for archiving purposes but hardly used. Also, there are only a few expensive implementations of it and certain components are proprietary and require very high computing power to create and read the associated JPEG 2000 codec |
| | MP4 | n. a. | Distribution | Conditionally recommended | Very widely used container, designed for H.264 but can also contain other video and audio codecs (AAC, MP3, MP2, MP1); ISO standard |
| | IMF (Interoperable Master Format) | n. a. | Post-production, distribution | Conditionally recommended | Very flexible and promising container, but not particularly widely used in either archiving or other areas of film production and evaluation. It does have potential, however, were it to be ported by the industry and were an archive subvariant to be defined and standardized |
| | MKV (Matroska) | n. a. | Archive | Recommended | Is open source and was developed explicitly for archive purposes; is today very actively used in combination with FFV1 by a specialist community and is being developed further; among other factors, standardization is in preparation |
| | MOV (QuickTime file format) | n. a. | Post-production, distribution | Conditionally recommended | Very widespread, proprietary container from Apple that can incorporate various codecs. Reservations apply, as Apple has changed the format significantly over time (earlier versions based, for example, on MP4) and no longer supports the specific Quicktime player for Windows operating systems |
| | AVI (Audio Video Interleave) | n. a. | Post-production, distribution | Conditionally recommended | Very widespread, proprietary container (Microsoft) that can incorporate various codecs. Reservations apply, as metadata such as the original creation date and timecodes can get lost when other containers are rewrapped to AVI |

| Category | Formats | Data rate | Work area | Suitability for archiving | Comments |
|---|---|---|---|---|---|
| | MXF (Material Exchange Format) | n. a. | Post-production, distribution, archive | Recommended | A flexible standard in broadcasting, can also pack text or XML files with metadata, for example, but at the same time is complex and more difficult to handle than other containers The AS-7 specification was developed by US state-owned archives, is somewhat cumbersome and requires relatively expensive software but may be useful as the only specific archive specification for use with JPEG2000 |
| | DCP (Digital Cinema Package) | n. a. | Post-production, distribution | Conditionnaly recommended | Not a container as such, but a defined folder structure that contains media in an MXF container. Specifications stipulate strong, lossy compression and the encryption that is often used makes handling archiving much more difficult; conditionally recommended for already existing DCPs only |
| Streaming formats | | | | | Pure distribution formats that work with proprietary, lossy compression (e.g. Flash, WebM, MPEG-4); not suitable as archive copies |
| Video cassettes | | | | | Today, physical video tapes can be regarded as obsolete and are no longer recommended as an archive format. In exceptional circumstances (where workflows, infrastructures, etc. are in place) the tape formats listed below may still be used, but archiving concepts based on copying content onto new tapes must be replaced as soon as possible |
| | DVCam | 25 Mbit/s | Recording, post-production | See above | Recommended conditionally as widely used by amateurs and semiprofessionals as a production format |

| Category | Formats | Data rate | Work area | Suitability for archiving | Comments |
|---|---|---|---|---|---|
| | Digital Betacam (nur SD) | 90 Mbit/s | Recording, post-production, archive | See above | Recommended as a transitional solution as an 10 bit 4:2:2 uncompressed files in SD if heritage institutions lack the infrastructure and expertise for the long-term preservation of files; still widely used, but uncertainty as Sony announced the cease of support of the format in 2023 |
| | HDCam SR (HD only) | 440/880 Mbit/s | Recording, post-production | See above | Recommended in recording mode with 4:4:4 sampling as a transitional solution to 10 bit 4:4:4 uncompressed HD files if heritage institutions lack the infrastructure and expertise for the long-term preservation of files; support by Sony only until 2023 |
| Optical data carriers for video | DVD | 4–9 Mbit/s | Distribution | Not recommended | Carrier not suitable for archiving |
| | BluRay | ca. 36 Mbit/s | Distribution | Not recommended | Carrier not suitable for archiving |
| IT-based storage | M-DISC | | Archive | Not recommended | Media not suitable for AV given data density and storage capacity; future of the production of reading devices is uncertain |
| | ODA (Sony) | | Archive | Not recommended | Sony proprietary format, no known archiving experience |
| | HDD | | | Conditionally recommended | Preconditions: Multiple copies at different locations, a selection of suitable interfaces, anticipated lifespan of 3 years |
| | RAID | | | Recommended | Recommended provided there are additional backup copies on other systems |
| | SSD | | | Not recommended | SSD storage relies on extremely small physical material structures that very quickly come up against their limits in the course of normal operations or through external influences and, accordingly, age very badly; consequently unsuitable for long-term storage |

| Category | Formats | Data rate | Work area | Suitability for archiving | Comments |
|---|---|---|---|---|---|
| | LTO (7 and 8) | | | Recommended | Format supported by consortium, possible as a write standard from LTO-5 LTFS onwards; LTO-5 to LTO-6 should be migrated soon, LTO-1 to LTO-4 should be migrated immediately |
| | DLT | | | Not recommended | Out of date and no longer supported. Files stored on DLT should be migrated to LTO immediately |

### 5.2.1 Supplementary notes on MPEG-4

The MP4 container and the H.264 codec are often used in combination with highly compressed (lossy) files that are optimized for the Internet. However, MPEG-4/H.264 may contain not only «visually lossless» compressed data and the more frequently used «lossy» compressed data, but also uncompressed $Y'C_BC_R$ 4:2:2 data. The latter is only rarely used, but in this configuration would be a perfectly suitable archive format

### 5.2.2 Supplementary notes on JPEG 2000, Motion JPEG 2000 and FFV1

The essentially open source JPEG 2000 (J2K) codec introduced in the year 2000 and is based on single images. It is a compressed file format that uses intra-frame compression based on wavelet compression technology. Wavelet compression delivers better visual results than conventional spatial JPEG compression for the same reduction in data volume, and can be used without compression as well as with lossless or lossy compression. Lossless compression reduces data volumes by half on average. This is a comparatively modest reduction. At the same time, the computing power needed to carry out the compression and play back the compressed data is very high. This fact and a lack of user-oriented applications has thus far restricted the codec's use. And standardized implementation (and therefore compatibility between different applications) is questionable to say the least. As a result, it is as yet unclear whether this file format will actually achieve widespread use in heritage institutions [Fig. 19]. However, the J2K codec is used with lossy compression to create projection elements for the cinema that comply with the international ISO/IEC 15444-1 standard. Projection elements are delivered in the form of digital cinema packages (DCPs). Since these elements are often the only material available to archives these days, it is necessary to get to grips with the codec in this form. It should be stressed that DCPs are actually not suitable for archiving. As mentioned, the J2K compression they use is lossy, they lack important metadata, and DCPs usually come with a digital security key to control copyright and usage rights (DRM, digital rights management). If the key is not available or if it expires after a certain period of time, it will be difficult to use the data even if it is in perfect condition.

These days, some major archives use J2K with lossless compression and an MXF container to digitally archive individual images derived, for example, from film digitization[12]. The lossy compressed version is used in the DCP film distribution format.

Motion JPEG 2000 was defined in part 3 of the ISO specification, which was implemented later. It is a container format that can store sequences of J2K files and the associated sound file and can be played as a movie. Creating and playing Motion JPEG 2000 files is also an exceptionally computing-intensive process, which has turned out to be a significant impediment to the use and proliferation of the format. There is still hardly any software for creating and playing the file format. It is therefore also rarely found in heritage institutions.

The best alternative to JPEG 2000 for lossless compression and archiving of moving images is the FFV1 codec, which was developed for archiving and is increasingly being used in heritage institutions. This open-source codec is ideally suited to archiving video files, ingesting data from digital tape formats and born-digital files. Videos are usually

12 e. g. Library of Congress FADGI MXF AS-07 http://www.digitizationguidelines.gov/guidelines/MXF_app_spec.html [9.9.2019]

Original image, TIFF
File size 100 %

High JPEG compression
File size 5 %

Spatial compression. Adjacent parts of the picture with similar colors are averaged out to form blocks of a single color

.

High JPEG 2000 compression
File size 3 %

Transformed values are produced and condensed using a complex computational processes called wavelet transformation, which results in a reduction in data. The visual impact is noticeably less with the same reduction in data

.

**Fig. 19: The visual impact of JPEG and JPEG 2000 compression.**

stored in the form of large single files containing the image stream. In contrast, films are often digitized and stored as a series of individual images [Section 5.4.2], can also be transcoded without information loss into an FFV1 stream, and this stream can be packaged in a Matroska container with sound, subtitles, etc. This produces a single MKV file with a video stream and checksums which are included by default, allowing automated integrity checks to be run on of each individual image (or parts of images, i. e. slices). Compared to the storage of individual images, this form of storage makes it easier to record to LTO tapes and to perform other copy processes and transfers.

The use of FFV1/MVK is also particularly interesting for archiving since it enables you to digitally archive film and video in the same format. This procedure also makes it easier to produce access copies of film material because there is already a stream which can be transcoded into suitable access formats more rapidly than individual images.

Moreover, when using FFV1/MKV for archiving film, the data volumes are reduced by one to two thirds and only a fraction of the number of files needs to be maintained compared to preserving individual images. This saves lots of time when reading (opening) and writing (storing) these files.

FFV1/MKV files may prove to be unattractive when it comes to post-production because no commercial professional post-production software supports their native import yet. To process the video stream in commercial software, the files have to be transcoded. There are, however, open-source tools that can process FFV1/MKV directly, without transcoding.

The developer community is aware of certain shortcomings in FFV1 that are relevant for digital archiving, and it is working towards creating future versions of FFV1 without these deficiencies. Since FFV1 is an open-source development, the community can be approached with specific requirements in the form of requests.

A lack of user-friendly implementations often hinders the wider use of this type of codec, which in turn makes it difficult to recommend them for use in archives. They either require in-depth IT knowledge, or the industry incorporates these codecs and formats into its product range. Whether formats targeted at archiving catch on in this way depends on whether enough important heritage institutions decide to use them or not.

J2K in MXF is used by the following major heritage institutions: Library of Congress, Washington; Cinematheque Royal, Brussels; Institut national de l'audiovisuel (INA), Bry-sur-Marne.

The following (heritage) institutions have opted to use FFV1: Cinémathèque Française, Paris; Österreichische Mediathek, Vienna; Archives of the City of Lausanne; Archives of Contemporary History, Zurich; Swiss Archive for the Performing Arts (SAPA), Zurich; Museum of Communication, Bern; more institutions world-wide are listed in Wikipedia.[13]

Uncompressed files are used by The Tate, London, for example.

This list is illustrative only and is far from complete.

### 5.2.3 Format recommendations for film

The digitization of film for archiving purposes means not only transferring the images but also the film element as an object into the digital domain. This means that, in addition to the image data that needs to be stored in sufficient resolution, other information recorded on the film and also its physical characteristics have to be documented and preserved as metadata as well.

13 https://en.wikipedia.org/wiki/FFV1#List_of_institutions_known_to_use_FFV1 [9.9.2019]

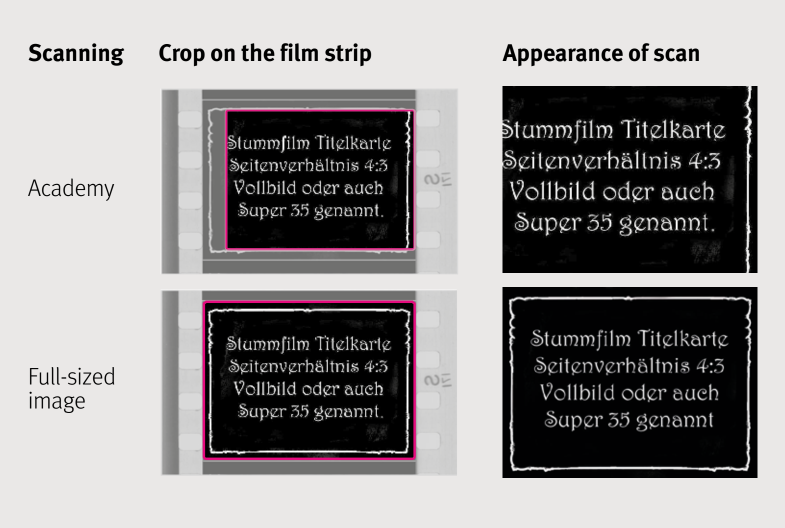



**Fig.20:** Cropped image as a result of reading a full-sized image with the Academy aspect ratio compared to a transfer with the correct aspect ratio. The same problem applies to analogue copies.

As a rule, at least the entire image frame has to be digitized as image data. If only an extract is scanned or copied across, image information is lost, and the aesthetic of the work is impaired. It is hard to tell, based on the new film element or the digital version, if the image was cropped when it was copied or scanned. With intertitles like the ones used mainly in silent movies, the wrong choice of film format is especially easy to see (▶ Fig. 20).

Unlike a raw scan, for digital projection elements the visible area of the image frame should correspond to that of the analogue projection. Because there is no exact definition of the cropping in analogue projection, however, you will have to decide exactly how much to crop in each case.

Please also note that a larger image frame than the film format envisaged by the creators can be chosen. The process of recording film images in the camera is similar to what happens when they are projected: The unexposed film moves along the film path and is exposed inside the camera, depending on the size and position of the film gate. The shape of this film gate may vary from one camera type to another and may expose a larger area of the film than is defined in the format standard. It is often the case that amateur cameras expose a larger area (▶ Fig. 20), but there are also film gates that place specific shapes next to the image frame, allowing the camera type used to be identified by examining the exposed film.

Information placed on the edges of the film material at the time of manufacture also becomes visible once it is developed. This may be information about the manufacturer and type of emulsion or so-called edge codes that provide information such as the place and year of manufacture of the film material. Fig. 19 shows an example of the information that can be found in the film margins.

This information must be preserved as metadata together with the image and audio data to document the source material and details of the digitization process for later research. Alternatively, it may be advisable to digitize not only the image frame but the entire width of the film strip (edge to edge scan). This secures all the meta information visible when a light is cast through the film. Not all scanners available on the market support this; in fact most scanners cannot read the full width of the film. Depending on the model, the maximum scannable area may be limited to the image frame or a slightly larger area, which is referred to as overscan.

Scanning the entire width of the film does, however, have some drawbacks too: A substantial portion of the sensor's resolution is used for the marginal area, leaving only the remaining resolution for the image frame. In the case of a 2 K scan, for example, the resolution of the film image will only be approx. 1.5 K.

Figure 23 shows a summary of the advantages and disadvantages of scanning the various areas of the film strip's surface.

Depending on the shape and resolution of the sensor and the driver software, scanners offer different options for the aspect ratio, resolution and crop of the film strip. The classic film scanning resolutions of 2048 × 1536 pixels for 2K and 4096 × 3072 pixels for 4K in a 4:3 aspect ratio are increasingly losing relevance for raw scans. Most scanners support an output of images in these resolutions but this requires scaling if the sensor does not correspond to the output resolution.

For cine film, with the exception of 16 mm negative and reversal film, digitizing at HD resolution is recommended because this can be done relatively cheaply nowadays; ideally, uncompressed files in HD 1080 p are generated with $Y'C_BC_R$ 4:2:2 color space and 10-bit color depth. This meets current requirements for professional (post)-production and can be considered future-proof for archiving purposes.

**Fig.21:** This is 16 mm film that was scanned edge to edge. Due to the shape of the camera's film gate, the film was exposed nearly across its whole width. The red line shows the crop that will be visible during projection.

The image frame – which has a 4:3 aspect ratio on the 16 mm film – should have a resolution of 1440 × 1080 pixels in the 16:9 aspect ratio of the HD image. If you are scanning edge to edge, the information of the margins covers pixels on both sides of the HD image. These are displayed as black pillars on the sides if the scan only covers the image frame of the film.

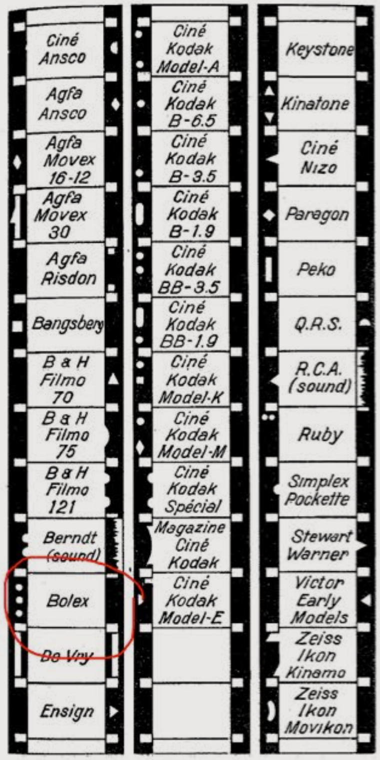
Be aware that uncompressed HD scanning results in very large data volumes that will involve considerable recurring data maintenance costs.

HD quality is not recommended for 16 mm negative and reversal material. The digitized image frame should have a minimum resolution of 2 K in a 4:3 aspect ratio with a RGB 4:4:4 color space and a 10 or 12-bit logarithmic or 16-bit linear color depth. However, this process is more expensive than digitization in HD and maintaining the files is more cumbersome, due to the even larger data quantities.

For high-quality sampling, individual DPX or TIFF image files (in folders, MXF or TAR) are now in widespread use and meet industry standards; a recommended alternative would be the use of FFV1 video files in MVK or JPEG 2000 in MXF [▶ Section 5.2.2 and 5.4.2].

Prints on 35 mm have to be scanned at a minimum resolution of 2 K for the image frame, while 4 K or more is recommended for 35 mm negatives. Although higher resolutions and greater color bit-depth may be desirable depending on circumstances, they can only be considered in exceptional cases at present due to their high costs (e. g. in the case of particularly valuable items or camera negatives).

Camera identification marks on film through exposure




Kodak edge codes for 16 mm film reveal the year of manufacture of the film material

| | US | UK | CANADA | FRANCE | GERMANY |
|---|---|---|---|---|---|
| 1925 | ■● | ◡— | ●L | | |
| 1926 | ▲● | —◡ | ●— | | |
| 1927 | ■▲ | L— | ●◡ | | |
| 1928 | ●●● | L◡ | L● | | |
| 1929 | + | + | —● | | |
| 1930 | ▲+ | +◡ | ◡● | | |
| 1931 | ●+ | +L | ◆ | | |
| 1932 | ■+ | +— | ◆● | | |
| 1933 | +▲ | ◡+ | ◆— | | |
| 1934 | +● | L+ | ◆L | ◡◡◡ | ■■■ |
| 1935 | +■ | —+ | ◆◡ | ◡■◡ | ●■● |
| 1936 | ● | ◡ | ●L | ■◡◡ | ■●● |
| 1937 | ■ | L | ●— | ◡◡■ | ●●■ |
| 1938 | ▲ | — | ●◡ | ■■◡ | ■●■ |
| 1939 | ●● | ◡◡ | L● | ◡■■ | ■■● |
| 1940 | ■■ | LL | —● | | |
| 1941 | ▲▲ | —— | ◡● | | |
| 1942 | ●■ | ◡L | ◆ | | |
| 1943 | ●▲ | —L | ◆● | | |
| 1944 | ▲■ | ◡— | ◆— | | |
| 1945 | ■● | —◡ | ◆L | | |
| 1946 | ▲● | L— | ◆◡ | | |
| 1947 | ■▲ | L◡ | ●L | | |
| 1948 | ●●● | + | ●— | | |
| 1949 | + | +◡ | ●◡ | | |
| 1950 | ▲+ | L | L● | | |

**Fig. 22:** A section of film which was scanned including the edges, showing information about the emulsion type, country and date of emulsion production as well as the camera used. The visible perforations also indicate that this is 16 mm film with no audio track.

| Scanning | Area on the film strip | Appearance in scanned image | Advantage | Disadvantage |
|---|---|---|---|---|
| Image only |  |  | Resolution of the sensor applies entirely to image information. For the use in projection often no further cropping is necessary. | All meta information is lost if not recorded otherwise. Meta information is partially lost if not recorded otherwise. The image does not receive the full resolution power the sensor offers. |
| Overscan |  |  | Metainformation is captured in its entirety. The aspect ratio of the image is and the form of its border area are preserved. Makes subsequent stabilization of the image much easier. | Meta information is partially lost if not recorded otherwise. The image does not receive the full resolution power the sensor offers. For the use in projection scaling and cropping is necessary. |
| edge-to-edge |  |  | Metainformation is captured in its entirety. The aspect ratio of the image is and the form of its border area are preserved. Makes subsequent stabilization of the image much easier. | Meta information is partially lost if not recorded otherwise. The image does not receive the full resolution power the sensor offers. For the use in projection scaling and cropping is necessary. |

**Fig. 23:** Film: Präsens-Film / SRF, photo credit: DIASTOR.

### 5.2.4 Format recommendations for videos

No single standard has been established worldwide for digitization with the aim of digitally archiving video material. Rather, experts are increasingly in agreement that the choice of codec, container and technical parameters such as data rate and resolution will continue to depend on the context (preservation concept, usage concept, etc.). Various possible contexts are therefore depicted below, together with specific recommendations and comments regarding the choice of format. These scenarios are vastly simplified, and may occur with many variations and in many combinations. It is not possible to cover all eventualities. The aim here is to provide basic guidance. It is assumed that a format needs to be chosen. In other words, the material cannot be archived in its existing format, nor has an internal archiving standard been defined.

#### Example 1: Documentary character

An archive wishes to digitize or convert into files the purely documentary content of a large collection of VHS, Betacam SP and Mini DV cassettes. The challenges involved in preserving the technical and visual characteristics (e. g. color reproduction) are relatively straightforward – it is primarily a question of preserving the content, to a lesser extent the visual impression. Nor are there any plans to use the video documents for new productions or upmarket exhibitions. Moreover, the archive does not specialize in AV records and has neither the specialist staff nor the specific infrastructure and financial resources required for the particular challenges of digitally archiving AV records.

In cases similar to this, digitizing in DV PAL and digitally archiving the material as DV files or MXF files (DV files plus metadata) is recommended, bearing in mind that DV uses a high degree of compression that will result in a loss of information and, depending on the condition of the original, may produce artefacts that are transferred across in the conversion process. The benefits of DV are that it is widely used, has SMPTE standardized specifications and is easy to use, enabling non-specialist archives to deal with the archive copies themselves. It also generates relatively small files, since data volumes for video are quite low (approx. 13 GB per hour).

A decision in favour of this compromise must, however, carefully assess the disadvantages and justify them in terms of archiving ethics: DV uses strong compression which results in information losses and – depending on the condition of the originals – produces artefacts at the time of digitization which will possibly cause further artefacts during subsequent migrations.

#### Example 2: Uncompromising solution

The second example involves the archiving of material such as video art. Irrespective of the original medium, the works need to be preserved in the long term with no loss at all. There are not huge quantities of such works, but reproducing them absolutely true to form (particularly their audiovisual appearance) is top priority. For this reason, the sampling rate, refresh rate, color sampling and scanning method (interlaced or progressive) must match those of the original.

In this instance, 8-bit or 10-bit 4:2:2 uncompressed (v210) or 10-bit 4:4:4 uncompressed (v410, for HD) are recommended codecs, depending on the existing/planned infrastructure in containers such as MXF, MKV or MOV. The resulting data volumes will be relatively high (100–780 GB per hour), and the considerable data retention costs will need to be carefully considered. However, these are pre-existing, well established standards that are relatively simple in technical terms and are quite undemanding.

**Example 3: Progressive compromise**
In this third example, an archive wishes to migrate existing video recordings on DigiBeta or HDCam, creating files for the purpose of archiving. The requirements for these video files are somewhat more exacting. Any loss of information or picture quality in these high-quality recordings must be avoided so as not to restrict possible future use. However, the financial resources for digital archiving are severely restricted and require a solution in which data volumes are a critical factor.

In this case, a lossless compressing codec such as FFV1 (version 3) or J2K (lossless) is recommended. With these codecs data volumes can be reduced by up to one third without losing any information (approx. 30–50 GB per hour). When choosing this progressive compromise, you need to be aware that these codecs currently call for a relatively large amount of specialist knowledge (open source software) and, for J2K, lots of computing power, and they are still being developed. So when opting for such a solution, you need to ensure either that specialist staff are available or you have established a very good relationship with your external supplier(s).

If this prerequisite cannot be met, the combination of a FFV1 codec in an MKV container could currently be recommended. J2K in MXF can also be recommended provided the necessary infrastructure (very powerful software and hardware) is available.

### 5.2.5 Recommendations for access copies (film and video)

Previous sections have provided recommendations for archival copies of films and videos. The requirements for access copies are different from those of archival copies (Section 3.3.6.3). In keeping with the many different types of usage and technical options, there are a large number of different solutions. For this reason, to highlight minimum requirements rather than making recommendations is the purpose of the following.

For distribution and screening in cinemas, broadcasting on television, and projection or consultation (streaming and downloading) via the web, a large variety of different formats of varying quality are ideal. You should choose a solution (file format, codec, resolution, aspect ratio and data carrier) that meets the specific requirements and fits in well with the existing infrastructure.

Minimum requirements for a access format are:

- correct playback speed
- correct aspect ratio
- synchronity of image and sound according to source file
- adequate resolution for the intended context (depending on how large the viewing is and the relevance of detail)

DVDs are still very widespread as carriers for access copies. However, there are clear indications that they will soon become a thing of the past (sales figures are declining dramatically, and new computers are no longer being equipped with read/write drives as standard).

The Memobase[14] requirements for the streaming format of video recordings can be used as a concrete example. Memobase works best[15] with:

- MPEG-4 format (set the «moov» atom at the start of the file to enable quick start and to skip forward in the video through the frame that has already been loaded)
- Video codec H.264 (avc1)
- Audio codec AAC

14 The information portal Memobase is a core product of Memoriav, allowing search (multilingual) and access to sound and image collections that are preserved in swiss institutions.

15 Variations from these parameters do not mean that such videos cannot be reproduced in Memobase. The system is set up to support all common web formats, codecs and protocols. However, this should be tested in individual cases.

- Data rate between 500Kb/s and 2Mb/s
- Resolution between 360p (16:9) and 480p (4:3) (The width of the player window in Memobase is 640 pixels. Images with a smaller or larger resolution are automatically scaled. The full screen mode, which can be selected, scales the images depending on the resolution of the monitor/display/projector.)

## 5.3 File repositories and long-term storage

### 5.3.1 Naming conventions

The file identifier consists of the file name and the file extension, which are separated by a full stop. Naming conventions not only make it possible to store data systematically, but also facilitate effective, secure communications within teams and with external partners. The file extension (for example: .pdf, .docx, .avi, etc.) indicates the file type. In some operating systems, the file management program only displays file extensions as an option rather than by default.

The most important factor here is that file names should not contain any special characters such as umlauts, punctuation marks or spaces, because these are used as control characters in some coding conventions and there is therefore a risk that the system will misinterpret the files (hyphens and underscores are exceptions to this rule and can be used with no problems).

To ensure compatibility between different users using a variety of applications (e.g. e-mail applications or optical data carriers formatted in accordance with ISO 9660), file names including file extensions should not exceed 31 characters. File paths (character strings that include both the storage location and the file name) should not exceed 255 characters in length (this applies particularly to NTFS-formatted disks).

### 5.3.2 Storage example: LTO

[▶ Section 4.3.7] Generally speaking, data from any generation can be migrated to every other generation, provided that the two corresponding devices are available. Migrating has many disadvantages, especially in terms of effort but it can also offer benefits for an archive. For example, the data and the files can be processed during a migration and even be transcoded and/or be packed into new containers.

To avoid any unnecessary migration, the recommendation is including only even-numbered or odd-numbered generations but not both, as this would involve considerable costs with no added benefits.

Odd-numbered generations:

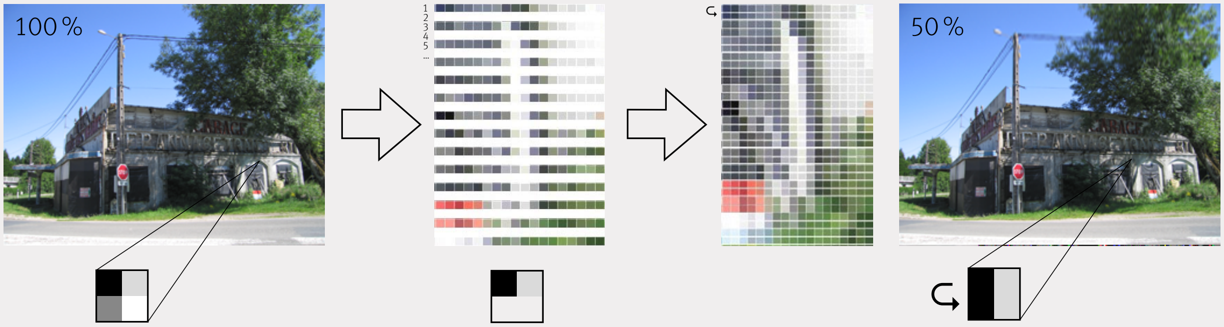
- For new backups use LTO-5 (where there is an existing infrastructure) or LTO-7 (where new equipment is being procured).
- Any existing tapes of generation 1 to 4 should be migrated directly to generation 7 as a matter of urgency (see above). The price of equipment and tapes has fallen to an acceptable level for heritage institutions because generation 8 has now been released.
- You can also start migrating generation 5 backups to generation 7.

Even-numbered generations:

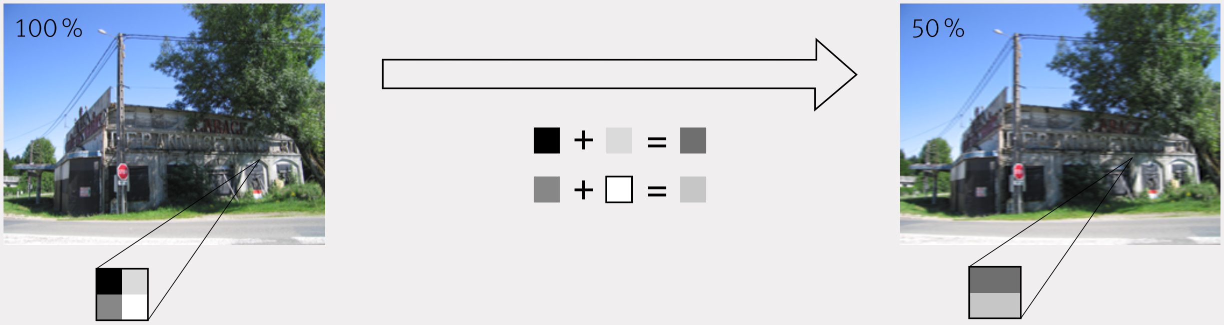
- Use LTO-8 for new backups now.
- Start migrating generation 6 backups to generation 8. The price of equipment and tapes will fall as soon as Generation 9 is available.
- Any remaining generation 2 and 4 tapes should be urgently migrated directly to generation 8.

The different file systems that are available on LTO all have their own advantages and disadvantages. When using LTFS you should avoid using the default compression setting

**Fictional compression 1 (K1)**
All the even-numbered lines in the picture are deleted, and the gaps in the display are filled by doubling up the odd-numbered lines. This results in a picture with 50 % of the information density and 50 % of the file size compared with the original.




**Fictional compression 2 (K2)**
The average color value is calculated for each pair of horizontally adjacent pixels. Both pixels are assigned this average color value. This results in a picture with 50 % of the information density and 50 % of the file size compared with the original.




**Using one type of compression then transcoding using the other**

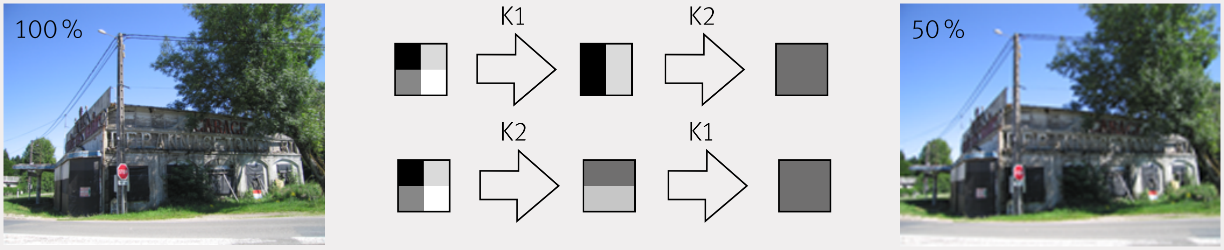
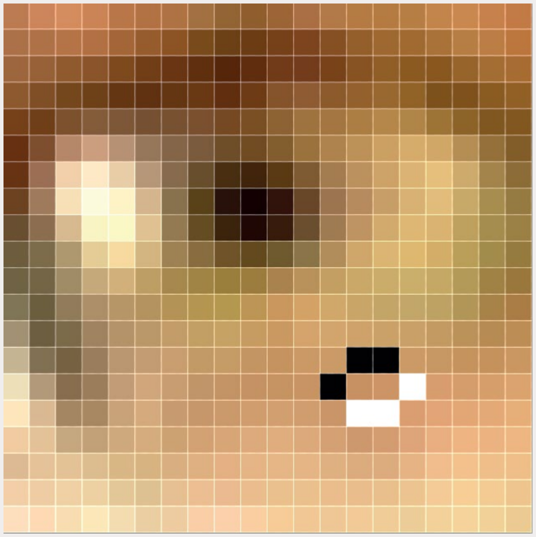
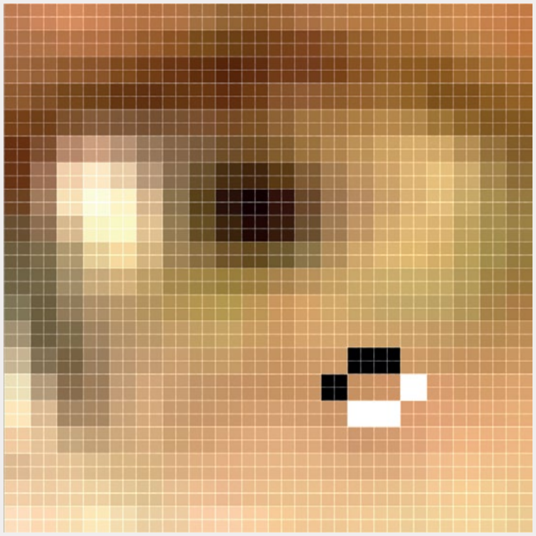



**Fig. 24: Abstract representation of the quality problems that can arise when pictures are transcoded.** It is wrong to assume that transcoding will not cause any problems if both codecs reduce the data volume by around the same amount for the same original material. Compressing twice in succession leads to a drastic loss of information. The resulting picture has an information density of 25 % compared with the original because the compression processes work differently and are «unaware» of each other. Consequently, the size of the file after transcoding is not 25 % of the original but 50 %. This means that by transcoding twice you are losing information without saving any storage space.

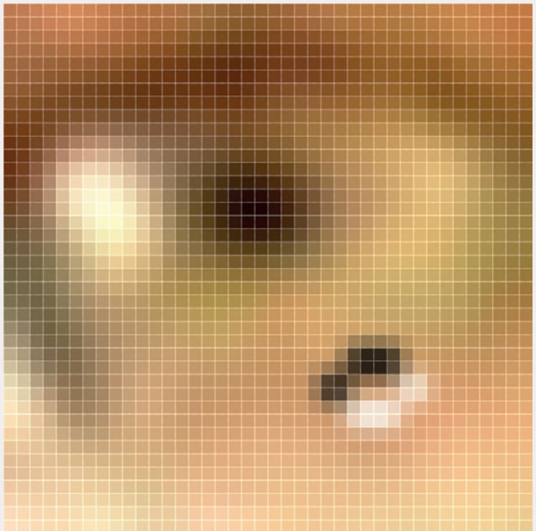
Original: 20 × 20 pixels



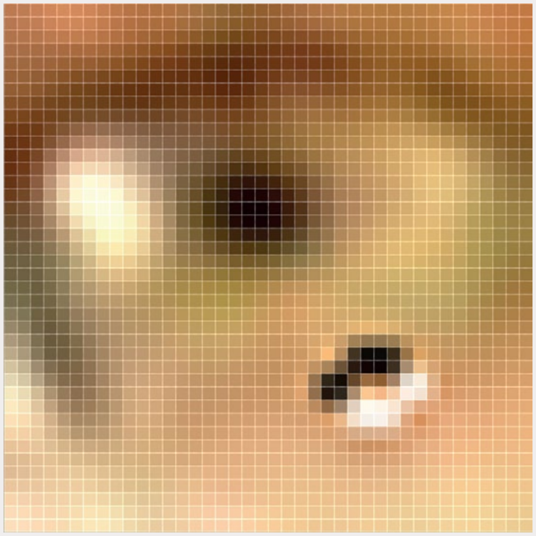
Scaled up to 40 × 40 pixels in Photoshop using various algorithms



Pixel repetition



Bilinear



Bicubic

**Fig. 25: The effect of image scaling.**

(i. e. it should be deactivated) because the compression algorithms are often proprietary and therefore compromise compatibility.

The LTO consortium's promise that each generation of the device would be able to read two earlier ones was broken with the introduction of LTO-8. LTO-8 devices can read LTO-7 cassettes but not LTO-6 cassettes. The «M8» format was also introduced with which LTO-7 cassettes can be formatted and used on LTO-8 devices as LTO-8.

### 5.3.3 Monitoring data integrity

Digital files can be easily (and unobtrusively) manipulated, corrupted or changed. This may occur manually and either intentionally or unintentionally, but files can also become corrupt if they are inadequately copied. File integrity («file fixity» [Section 3.4.4 Data integrity]) can be verified using checksums. These are calculated using what are known as hash functions. Different hash functions are calculated in different ways, have varying levels of complexity and usage and are suitable for different applications. Various utility programs are available for generating and using check sums. What they all have in common is that they always provide the same result if the file being checked has not changed. It doesn't matter what operating system the file was created on and the check sum was calculated on, or what operating system the file is checked on. So the check sum is a sort of «fingerprint» for the file. Applications such as FFmpeg also make it possible to calculate check sums for individual images in a video file. Message Digest-Algorithm 5 is currently the most popular check sum utility in the video industry, but there are others such as Secure Hash Algorithm 1 (SHA-1) and SHA-256. Check sums should be generated as soon as possible after a video file has been created to ensure that the material in the file has not become corrupt (no bit rot or read/write errors). Depending on the application, it may be beneficial for the video file and its check sum always to be stored in the same folder to make automated checking easier. If you are dealing with large numbers of individual images, it is recommended you keep all the individual check sums together in a text file. The use of check sums should be automated to avoid any errors occurring when they are being manipulated.

## 5.4 Codecs and transcoding

Transcoding (code conversion) takes place during the video production process to tailor the file format to the requirements of the individual task. Archiving requirements are not usually the same as those of previous stages in the production process. So producing an audiovisual document does not automatically result in archivable files, and transcoding may be necessary when they are archived.

### 5.4.1 Principles of transcoding

Depending on the compression procedure used, each codec has certain properties that are optimized for a particular application. Since uncompressed video files result in very large volumes of data, reducing this data by compressing it is an important consideration that involves compromising on quality. The biggest compromises are made where they will cause the fewest problems, depending on the application. When transcoding from one codec to another, the combination of different compression procedures can have a negative impact on data. Even if the file size remains unchanged, transcoding can result in picture information being lost if codecs reduce data in different ways [Fig. 24].

In archiving, transcoding is mainly used to convert unarchivable original files into a format suitable for archiving. Depending on the preservation strategy, one aim of transcoding may also be to minimize the number of different file formats used. Alternatively, an archive may specify several file formats for video files of different priorities – top-priority items could be stored in an uncompressed format and lower-priority material could be stored in a space-saving file format that is still suitable for archiving purposes. Transcoding can also be postponed until it becomes imperative (e. g. due to obsolescence) in order to avoid unnecessary migration. This option obviously calls for the systematic and consistent monitoring of technical developments.

Another classic example of transcoding is converting between PAL and NTSC television standards. Lots of properties have to be changed here:

DV PAL has 4:2:0 subsampling and a picture containing 720 × 576 square pixels at an aspect ratio of 16:15, while DV NTSC has 4:1:1 subsampling and a picture containing 720 × 480 square pixels at an aspect ratio of 8:9.

The frame frequency (50 vs. 60 half-frames per second) also has to be changed, and the color space has to be modified.

In conclusion, the following recommendations are applicable.

As little transcoding as possible should be undertaken (use long migration cycles) to create as few problems as possible. Each transcoding can generate artefacts. This issue is similar to the generational problems experienced in analogue video.

Transcoding should be well documented and recorded in metadata, as this information can be used during subsequent transcoding to avoid or rectify problems.

When an archive acquires digital material, its transcoding history often cannot be traced, unfortunately.

As a rule, heritage institutions should not undertake any transcoding that reduces data volumes lossily. When transcoding with a codec that uses lossy compression, information gets lost, particularly if data volumes are reduced in the process.

Caution should be exercised even when transcoding using an equivalent codec, because even if the data volumes are retained, lossy codecs can result in lost information if the codec's compression procedures are incompatible.

Transcoding using a codec with less compression cannot improve the quality of existing data; at best it can only maintain it. However, transcoding to a less compressed file format may improve the results of future processing and increase archivability.

Scaling up digital images to a higher resolution is also considered to be a form of transcoding. Scaling up from SD to HD resolution is often carried out in the video industry and is seen as unproblematic, as it's only the display area that is being enlarged. It is assumed that the image structure is retained or even improved and that there is no reduction in data volumes. However, this is a fallacy. When scaling up, every single pixel in the picture is affected, and new pixels are actually fabricated. A variety of algorithms exist, the results of which vary considerably [Fig. 25].

In the case of video art in particular, the aim must be to retain the pixel structure of the original throughout all stages of the preservation process, just as one would make every effort to present a work at an exhibition in conditions as close as possible to those of the original.

Particularly problematic are cases where SD material is scaled up to HD resolution and then compressed so much that the resulting HD file is smaller than the original SD file. In this case, the image structure is massively and irrevocably changed, firstly by the scaling up and then once again by being compressed.

### 5.4.2 Storing as a series of individual images

35 mm feature films are subdivided due to the limited length of film reels. In the early years of cinema, the maximum length of a projection reel was 305 metres which, at a projection speed of 24 frames per second, equates to a running time of approximately 10 minutes and 16,000 or so images. From the early 1930s onwards, longer rolls of up to 610 metres were introduced, equating to about 32,000 images.

Following digitization, this same subdivision has to be retained by assembling the respective amount of images in a series of folders. Depending on the length of the film, the result is a series of folders that correspond to physical reels.

Check sums can be generated either per folder or per individual image. In both cases, it is recommended automating the check sum creation process.

Storing moving pictures as a series of individual images offers certain advantages, but also has disadvantages compared with storing them as a single file [▶ Section 4.3.8 and 5.2.2]. In general, individual images are used for high-resolution and special formats. Accessing the individual images, it is not immediately possible to play them back. However, this may not be possible for media files either, depending on the file size and compression used. Instead of having very large individual files, there is a large number of smaller files. If a single file is seriously damaged, less data is lost, the problem can be contained more easily, and it is simpler to repair or restore than if a defect occurs in a very large video file. But in contrast, large individual files are considerably easier to manipulate (particularly with regard to reading them and transferring data e. g. for storage on LTO), they involve less time and computing power, and have a lower risk of conversion errors.

When storing a series of individual images, the following recommendations apply:

- Ensure that information concerning the playback speed is not lost.
- Store the sound separately and in an uncompressed or lossless compressed format (in line with the playback speed). Visual and audio markers must be present for synchronization purposes.
- Avoid any confusion due to the large number of individual images. Naming conventions are particularly important, and the images must be subdivided into several files depending on how many of them there are.

## 5.5 Documentation and metadata

The metadata for long-term preservation must contain all the information needed to find, manage, play back, identify and maintain files. ▶ Section 3.5 for details on metadata categories and its various functions.

A range of metadata standards exist to support the systematic documenting and recording of metadata for various different functions. Adhering to a standard or a combination of several standards, or adapting an existing standard to meet specific needs is recommended.

A variety of possible approaches exist for structuring and storing metadata. It can be included in the container or held externally in the database used to manage the documents. Both alternatives have advantages and disadvantages. If the metadata forms part of the archive package, it will form a closed unit that will remain linked during migration. If the metadata is stored externally, it will be easier to update it (e. g. to include details of screenings), since the archive package will not need to be amended then reassembled each time.

One key prerequisite for long-term preservation is that the search tool and information in the database and the externally stored metadata must be securely backed up.

This applies in particular to descriptive metadata, the scope and content of which may vary considerably. Elaborating this structure forms part of the archiving strategy.

### 5.5.1 Examples of metadata standards

A few examples of indexing standards commonly used in archiving are included below with brief explanations. This list is not exhaustive

**ISAD (G):** «As stated in the preface to the second edition in 2000, the ISAD(G) international indexing standard provides general guidelines for drawing up archival descriptions. It must be used in conjunction with existing national standards, or be used as a basis for developing such standards. The Swiss guidelines for implementing ISAD(G) that now exist are therefore national guidelines based on international standards for document indexing. They take account of the specific national features of the Swiss archiving environment and its indexing regulations.»
Reference: https://vsa-aas.ch/wp-content/uploads/2015/06/Richtlinien_ISAD_G_VSA_d.pdf [9.9.2019]

**PREMIS:** «The PREMIS (PREservation Metadata: Implementation Strategies) Data Dictionary for Preservation Metadata is the international standard for metadata to support the preservation of digital objects and ensure their long-term usability. Developed by an international team of experts, PREMIS is implemented in digital preservation projects around the world, and support for PREMIS is incorporated into a number of commercial and open-source digital preservation tools and systems. The PREMIS Editorial Committee coordinates revisions and implementation of the standard, which consists of the Data Dictionary, an XML schema, and supporting documentation.»
References:
Caplan, Priscilla, *PREMIS verstehen*, 2009, http://www.loc.gov/standards/premis/understanding_premis_german.pdf [9.9.2019]
PREMIS Data Dictionary: www.loc.gov/premis/v2/premis-2-0.pdf [9.9.2019]
PREMIS-Website: www.loc.gov/standards/premis/ [9.9.2019]

**METS:** «The METS schema is a standard for encoding descriptive, administrative, and structural metadata regarding objects within a digital library, expressed using the XML schema language of the World Wide Web Consortium. The standard is maintained in the Network Development and MARC Standards Office of the Library of Congress, and is being developed as an initiative of the Digital Library Federation.»
«The Matterhorn METS Profile, developed in cooperation with Docuteam and the Archives de l'Etat du Valais in Switzerland, is now registered. It describes the core of the digital object model used by the Docuteam software tools to support digital archiving. This may be the first profile that describes the use of EAD within METS in any detail.»
References:
http://www.loc.gov/standards/mets/ [9.9.2019]
http://www.loc.gov/standards/mets/news112912.html [9.9.2019]

**Dublin Core (DC):** «The Dublin Core Metadata Element Set is a vocabulary of fifteen properties for use in resource description. The name ‹Dublin› is due to its origin at a 1995 invitational workshop in Dublin, Ohio; ‹core› because its elements are broad and generic, usable for describing a wide range of resources.
The fifteen element ‹Dublin Core› described in this standard is part of a larger set of metadata vocabularies and technical specifications maintained by the Dublin Core Metadata Initiative (DCMI). The full set of vocabularies, DCMI Metadata Terms [DCMI-TERMS], also includes sets of resource classes (including the DCMI Type Vocabulary [DCMI-TYPE]), vocabulary encoding schemes, and syntax encoding schemes.»
DC was standardized by different standardization bodies (ISO 15836:2009; ANSI/NISO Z39.85-2012; IETF RFC 5013). Different av-specific standards were developed using DC as starting point (see PBCore and EBUCore).
Reference: https://www.dublincore.org/specifications/dublin-core/dces/ [9.9.2019]

**PBCore:** «PBCore is a metadata standard designed to describe media, both digital and analog. The PBCore XML Schema Definition (XSD) defines the structure and content of PBCore.»
Reference: http://pbcore.org/schema/ [15.1.2015]

**EBUCore:** «EBU Tech 3293 (EBUCore) is the flagship of EBU's metadata specifications. In 2000, the original goal was to refine the semantics of the Dublin Core elements for audio archives. Today, the domain of use of the EBUCore specification is much broader and is no longer limited to audio or archives.»
Reference: https://tech.ebu.ch/MetadataEbuCore [15.1.2015]

**MPEG-7 Multimedia Content Description Interface:**
An international standard for describing multimedia data, images, videos, sound, etc. Requires XML to display content, supports description at sequence/shot level, can also handle non-text-based metadata (e. g. the indexing of camera movements and image textures).
References:
MPEG-7-Übersicht: http://mpeg.chiariglione.org/standards/mpeg-7 [15.1.2015]
MPEG-7 und Dublin Core für Video: http://www8.org/w8-papers/3c-hypermedia-video/comparison/comparison.html [15.1.2015]

## 5.6 Toolboxes

No complete infrastructure packages exist for use in audiovisual archiving. Standards for media and metadata packages have not yet become universally established, and there is a lack of user-friendly implementations.

Individual items that are relevant for the archiving of audiovisual material plus various current examples are listed below:

- **Players** for viewing audiovisual files
  VLC, MPEG Streamclip, ffplay, avplay, QuickTime Player 7 (is more universal than the latest version) and 10.
- **Database** (management and search tools)
  As yet there are very few database systems aimed at audiovisual archive material. Consequently, it can be difficult to accommodate the specific properties of audiovisual files in existing databases in a meaningful manner. As a result, a large number of solutions have been individually developed for this purpose.

- **Tools for reading metadata**
  EXIF data consisting of predominantly technical information relating to files can be retrieved in text editors and in some playback applications. Additional applications exist for accessing the metadata stored in media file headers. Unfortunately, not all these applications read out the header information in its entirety.
  Examples: MediaInfo, Videospec (not being developed any further), ffprobe, avprobe, libav, QCTools, DROID, BitCurator
- **Tools for writing metadata records**
  These tools can be used to add extra metadata to headers in media files: BWF MetaEdit
- **Tools for packaging metadata**
  These tools combine metadata records and media files from backup packages:
  CURATOR Archive Suite (Fraunhofer Inst.), MXF4Mac, BagIt (LoC, creates AIPs)
- **Tools for transcoding media files**
  The following applications support transcoding: MPEG Streamclip, ffmpeg, avconv and ffmbc

## 5.7 Originals

Following preservation and digitization, the original material does not become any less important, and should still be preserved under the best possible conditions.

This is important as it is quite likely that a new, better quality digitization process will become possible, or the digital data may be lost, requiring the original to be re-digitized. However, such subsequent digitization may be hindered or even made impossible for the reasons stated in the introduction [Section 2].

Any decision on de-accessioning archiving originals or not must be made on a case-by-case basis, since this will depend on many parameters. An expert should always be involved in such circumstances.

And apart from preserving the contents of films and/or video tapes for posterity, the original physical containers are worth retaining as cultural artefacts.

In the archiving process, you can never be certain whether you have captured all the relevant information, relating to both the content and the form, even when this is well documented and backed up with photographic evidence.

See also the Memoriav position paper on the issue of preserving physical originals [http://memoriav.ch/wp-content/uploads/2016/02/Memoriav_Positionspapier_Physische_Datentraeger.pdf]

## 5.8 Equipment

Conserving and maintaining the original equipment that is needed to play back the source material forms an important part of the process of long-term preservation. Without the necessary playback devices, the media become unreadable and therefore worthless as an archival record. This subject is not covered by these guidelines. However, reference can be made to the recommendations published by Memoriav.

## 6.1 Glossary

*There are plans to produce a glossary containing the most important terms used in these recommendations, but unfortunately we have been unable to do so in the current version.*

## 6.2 Image credits

Figures 9, 10 and 11a-11d: Agathe Jarczyk, all other illustrations: David Pfluger

## 6.3 Standards


FIPS PUB 180-4, Secure Hash Standard (SHS). National Institute of Standards and Technology, Gaithersburg, MD, March 2012

ISO 12639:2004, Graphic technology – Prepress digital data exchange – Tag image file format for image technology (TIFF/IT). International Organization for Standardization, Geneva 2004

ISO 14721:2012, Space data and information transfer systems – Open archival information system (OAIS) – Reference model

ISO 18943:2014, Imaging materials – Magnetic hard drives used for image storage – Care and handling. International Organization for Standardization, Geneva 2014

ISO/IEC 14496-14:2003, Information technology – Coding of audio-visual objects – Part 14: MP4 file format. International Organization for Standardization, Geneva 2003

ISO/IEC 14496-15:2010, Information technology – Coding of audio-visual objects – Part 15: Advanced Video Coding (AVC) file format. International Organization for Standardization, Geneva 2010

ISO/IEC 15444-1:2004, Information technology – JPEG 2000 image coding system: Core coding system. International Organization for Standardization, Geneva 2004

ISO/IEC 15444-1:2004/Amd 1:2006, Profiles for digital cinema applications. International Organization for Standardization, Geneva 2006

ISO/IEC 15444-1:2004/Amd 2:2009, Extended profiles for cinema and video production and archival applications. International Organization for Standardization, Geneva 2009

ISO/IEC 15444-1:2004/Amd 3:2010, Profiles for broadcast applications. International Organization for Standardization, Geneva 2010

ISO/IEC 15444-1:2004/Amd 4:2013, Guidelines for digital cinema applications. International Organization for Standardization, Geneva 2013

ISO/IEC 15444-1:2004/Amd 5:2013, Enhancements for digital cinema and archive profiles (additional frame rates). International Organization for Standardization, Geneva 2013

ISO/IEC 15444-1:2004/Amd 6:2013, Updated ICC profile support, bit depth and resolution clarifications. International Organization for Standardization, Geneva 2013

ISO/IEC 15444-3:2007, Information technology – JPEG 2000 image coding system: Motion JPEG 2000. International Organization for Standardization, Geneva 2007

ISO/IEC 23008-2:2013, Information technology – High efficiency coding and media delivery in heterogeneous environments – Part 2: High efficiency video coding. International Organization for Standardization, Geneva 2013

Linear Tape File System (LTFS) Format Specification. Version 2.0.1, 2011, http://avpres.net/pub/LTFS_2_0_1.pdf, [1.4.2015]

Pirazzi, Chris, Cherna, Tim und Hoddie, Peter, *Technical Note TN2162, Uncompressed Y′$C_BC_R$ Video in QuickTime Files*, in: Mac Developer Library, https://developer.apple.com/library/mac/technotes/tn2162/_index.html#top [26.3.2015].

Digital Cinema Initiatives, *DCI System Requirements and Specifications for Digital Cinema, DCI Specification, Version 1.2 with Errata as of 30 August 2012 Incorporated*, o. O., 2012, http://www.dcimovies.com/specification/ [26.3.2015].

PREMIS Editorial Committee, *PREMIS Data Dictionary for Preservation Metadata Version 2.2,* o. O., 2012, http://www.loc.gov/standards/premis [26.3.2015].

Recommendation ITU-R BT.601-7 (03/11), Studio encoding parameters of digital television for standard 4:3 and wide screen 16:9 aspect ratios. ITU, Geneva 2011

Recommendation ITU-R BT.709-5, Parameter values for the HDTV standards for production and international programme exchange. ITU, Geneva 2002

RFC 1321, The MD5 Message-Digest Algorithm, Internet Engineering TaskForce (IETF)

SMPTE 268M-2003, SMPTE Standard for File Format for Digital Moving-Picture Exchange (DPX). Version 2.0. Society of Motion Picture and Television Engineers (SMPTE)

## 6.4 Additional information

Abrams, Stephen, *Instalment on «File Formats», in: Digital Curation Manual,* o. O., 2007, http://www.dcc.ac.uk/resource/curation-manual/chapters/file-formats [26.3.2015].

Casey, Mike, *Indiana University Media Digitization and Preservation Initiative (MDPI) White Paper: Encoding and Wrapper Decisions and Implementation for Video Preservation Master Files,* o. O., 2017 https://mdpi.iu.edu/doc/MDPIwhitepaper.pdf [11.4.2017].

Dappert, Angela, Squire Guenther, Rebecca, Peyrard, Sébastien [ed.], *Digital Preservation Metadata for Practitioners: Implementing PREMIS».* Cham, 2016.

David Pfluger, *Eigenschaften von 16-mm Umkehrmaterial in der Digitalisierung in High Definition,* Bern, 2011, http://memoriav.ch/wp-content/uploads/2014/07/16mmtohd_dossier-pdf_web.pdf [26.3.2015].

Edmondson, Ray, *Audiovisual Archiving: Philosophy and Principles,* Paris, 2004, http://unesdoc.unesco.org/images/0013/001364/136477e.pdf [26.3.2015].

Gfeller, Johannes, Jarczyk, Agathe, Phillips, Joanna, *Kompendium der Bildstörungen beim analogen Video,* Zürich, 2013

International Association of Sound and Audiovisual Archives, *IASA-TC 03. The safeguarding of the audiovisual heritage ethics, principles and preservation strategy,* o. O., 2017, http://www.iasa-web.org/IASA_TC03/TC03_English.pdf [28.2.2018].

International Association of Sound and Audiovisual Archives, *IASA-TC 04. Guidelines on the Production and Preservation of Digital Audio Objects,* o. O., 2009, http://www.iasa-web.org/audio-preservation-tc04 [26.3.2015].

International Association of Sound and Audiovisual Archives (ed.) *Ethical Principles for Sound and Audiovisual Archives.* IASA Special Publication No. 6, 2011, https://www.iasa-web.org/ethical-principles [28.2.2018].

Kompetenznetzwerk Langzeitarchivierung, *nestor Handbuch. Eine kleine Enzyklopädie der digitalen Langzeitarchivierung,* Boizenburg, 2010, http://www.nestor.sub.uni-goettingen.de/handbuch/index.php [26.3.2015].

Leippe, Anna, *8 mm Ewigkeiten. Vom analogen 8 mm Schmalfilmformat zur digitalen Kopie,* Staatliche Akademie der Bildenden Künste (Masterthesis KNMDI), Stuttgart 2010

Library of Congress, *NDSA Levels of Preservation,* o. O., http://www.digitalpreservation.gov:8081/ndsa/activities/levels.html [3.4.2017].

The Little Archives of the World Foundation / ECPA, *Video Tape Identification,* o. O., 2008, http://www.little-archives.net/guide/content/formats.html [30.3.2015]

Memoriav (Hg.), *Video. Die Erhaltung von Videodokumenten,* 2006, http://memoriav.ch/video/empfehlungen-video/ [30.3.2015]

National Film Preservation Foundation (Hg.), *The Film Preservation Guide. The Basics for Archives, Libraries, and Museums,* o. O. 2004, http://www.filmpreservation.org/preservation-basics/the-film-preservation-guide [30.3.2015]

Poynton, Charles, *Chroma subsampling notation,* o. O., 2002, http://scanline.ca/ycbcr/Chroma_subsampling_notation.pdf [26.3.2015].

PrestoCentre, http://www.prestocentre.org/ [26.3.2015].

Pritchard, Brian R., *Identifying 35 mm Films,* o. O., 2011, http://www.brianpritchard.com/35mm%20Film%20Identification%20Version%203.2.pdf [30.3.2015]

Pritchard, Brian R., *Identifying 16 mm Films,* o. O., 2013, http://www.brianpritchard.com/16mm%20Identification%20Version%201.02.pdf [30.3.2015]

Romeyke, Andreas, *Fact Sheet Matroska/FFV1 for Decision-Makers,* 2017, http://andreas-romeyke.de/software.html#_ffv1_matroska_factsheet_for_managment_decision_makers [4.6.2018]

Rosenthal, David S. H., *LOCKSS: Lots of copies keep stuff safe,* http://171.66.236.16/locksswiki/files/NIST2010.pdf [26.3.2015].

Santi, Mirco, *«Petit, simple, bon marché». Storia tecnologica e pratiche d'archivio del Pathé Baby,* Università degli Studi di Udine, 2011

Stauderman, Sarah, Messier, Paul, *Video Format Identification Guide,* o. O., 2007, http://videopreservation.conservation-us.org/vid_id/ [22.4.2015]

Texas Commission on the Arts, *Videotape Identification and Assessment Guide,* 2004, http://www.arts.texas.gov/wp-content/uploads/2012/04/video.pdf [30.3.2015]

Wright, Richard, PrestoSpace Deliverable D13.4 Repositories. Digital Repositories Explained, http://www.prestospace.org/project/deliverables/D13-4.pdf [26.3.2015].

## 6.5 Memoriav

Memoriav, the Association for the Preservation of the Audiovisual Heritage of Switzerland, is actively and sustainably involved in preserving, valorizing and ensuring the broad use of Switzerland's audiovisual heritage, including photographs, sound recordings, films and video recordings as well as the documentation and context information required to understand them.

Memoriav organizes a network of all the institutions, suppliers and individuals involved and interested in this task, and is committed to basic and continuing training. Memoriav collaborates in the running of centres of excellence and skills networks in the fields of photos, sound, film and video, and seeks to establish, apply and expand the specialist skills required in these areas. Memoriav monitors technological developments and also national and international standards for preserving audiovisual heritage, uses this information to develop its own recommendations and takes part in a national and international exchange of knowledge.

Memoriav is active in all of Switzerland's linguistic and cultural regions. The association advises institutions and provides support for projects, both financially and in terms of expertise.

With its Memobase online platform, Memoriav facilitates the access to and usage of Switzerland's audiovisual cultural heritage.

## 6.6 Uncompleted sections

The following sections will be revised or included in future versions of these recommendations:

5.6 Toolboxes
6.1 Glossary

ASSOCIATION POUR LA SAUVEGARDE DE LA MÉMOIRE AUDIOVISUELLE SUISSE
VEREIN ZUR ERHALTUNG DES AUDIOVISUELLEN KULTURGUTES DER SCHWEIZ
ASSOCIAZIONE PER LA SALVAGUARDIA DELLA MEMORIA AUDIOVISIVA SVIZZERA
ASSOCIAZIUN PER IL SALVAMENT DA LA CULTURA AUDIOVISUALA DA LA SVIZRA
ASSOCIATION FOR THE PRESERVATION OF THE AUDIOVISUAL HERITAGE OF SWITZERLAND